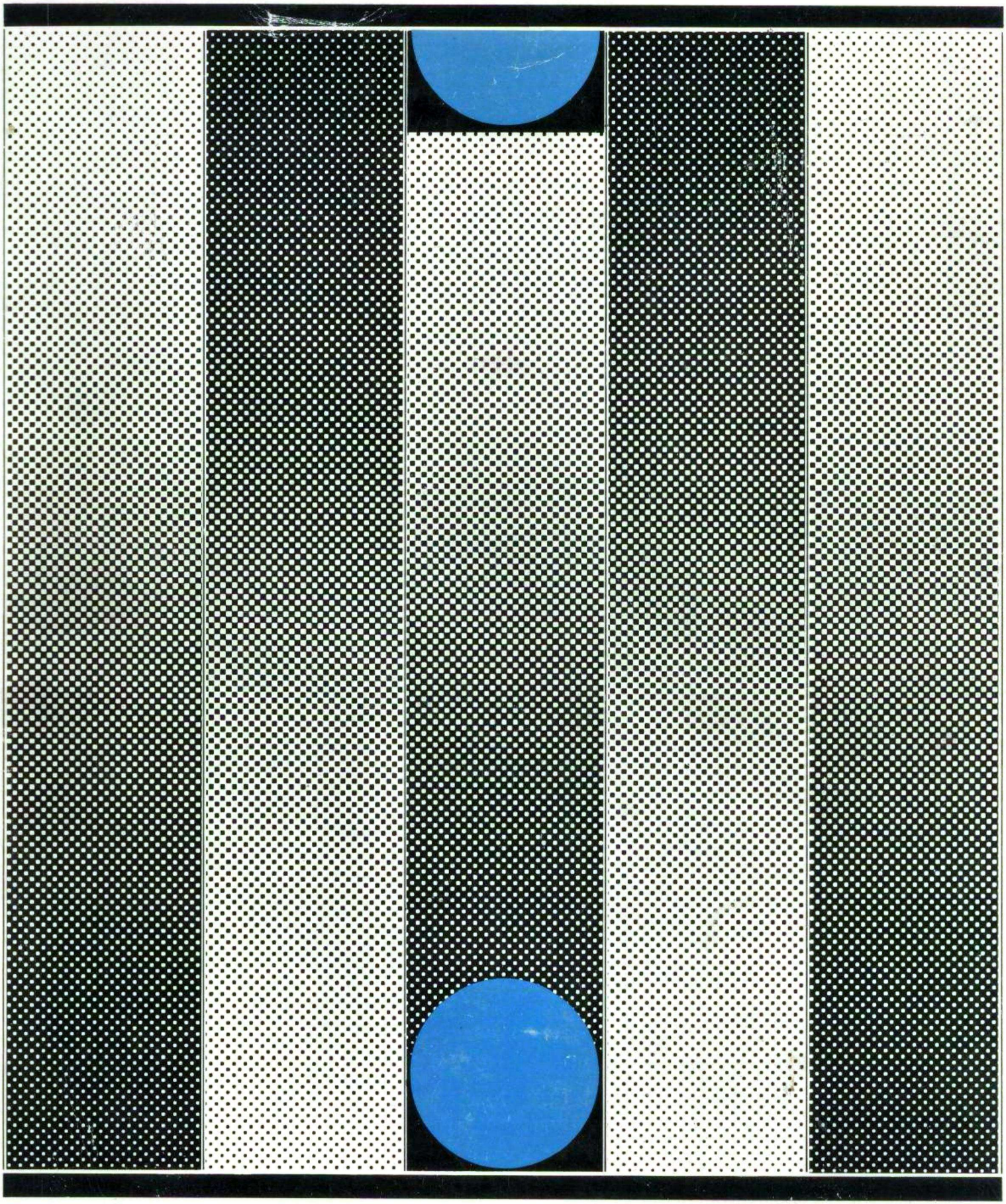

practical aspects of electric motor controls

Telemecanique

FOREWORD

This publication is intended for people interested in Control Equipment Application and Design.

It is divided into six sections.

COMPONENTS

This section deals with contactors, control relays, isolators, protection and sensing relays, pilot devices and equipment used in the construction of a system.

For each of these component ranges we have:
— briefly explained their operation,
— specified their special characteristics,
— indicated the main selection factors.

STANDARDISATION OF ELECTRICAL SCHEMATICS

To enable the user to easily understand or design an automatic control scheme the principal graphic symbols are shown along with the rules to be observed for the design of circuit diagrams in accordance with present standards.

STARTING, SPEED REGULATION AND BRAKING OF INDUCTION MOTORS

A special chapter is devoted to the starting of induction motors, their characteristics and the choice of the type of starter as a function of the load.

BASIC SCHEMATICS

This section is devoted to an examination of basic control circuits.

Each schematic or group of schematics in the same category is accompanied by remarks concerning:
— the operation of the power circuit,
— the operation of the control circuit,
— special characteristics,
— problems to be avoided in the design of the system and the selection of equipment.

The basic reference numbers indicated are helpful for the specification of the desired equipment.

DEVELOPMENT OF AN AUTOMATIC SYSTEM

The development of a single or repetitive system is discussed in this chapter.

By the use of a practical example the manufacturing and installation process is presented:
— component layout,
— assembly,
— wiring,
— testing,
— installation.

This example is concluded by a few practical trouble shooting hints.

DATA

In conclusion, we have listed some practical data which may be helpful to the reader.

It is our hope that this brochure will help in the application of Telemecanique control components.

TELEMECANIQUE

For further information please write to your Telemecanique Sales Office.

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introduction

Electric power is supplied by means of a distribution network but cannot be continuously connected to equipment. Power switching systems must be used which allow the making and breaking of electric power from the mains to the load.

Switchfuses, isolators, circuit breakers and contactors are used to provide this function called "power switching".

In some cases, the operator is at some distance from the power switching units and remote control must be provided. Relays are used for this purpose and may be controlled by pilot devices, push buttons for example.
Contactors, with their electromagnets, fulfil both power switching and remote control functions.

The action performed by the latter is shown by either an illuminated display or a sequence interlock with another component.

These electrical circuits, called "interlock circuits", are made by contacts incorporated in the contactor.

GENERAL

A contactor is a mechanical switching device controlled by an electromagnet.

When the coil of the electromagnet is energized the contactor closes and, by means of contacts, completes the circuit between the main supply and the load. The moving part of the electromagnet which drives the moving contacts operates:
- by rotation, pivoting on a shaft,
- by sliding in parallel to the fixed parts,
- by a combination of these two movements.

As soon as the coil is de-energized the contactor opens under the effect:
- of the pole pressure springs,
- of the moving armature return spring,
- of gravity for some contactors (the moving contact assembly tending naturally to resume its initial position).

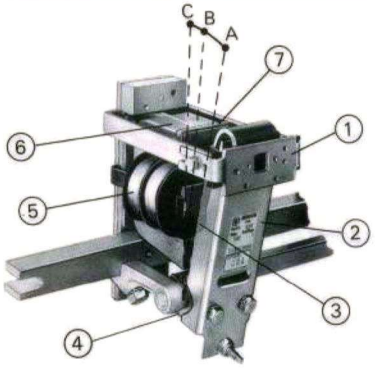
Contactors offer a great number of advantages, such as:
- breaking high currents by means of a low current device,
- providing intermittent as well as continuous service,
- executing a remote, automatic command using cable of a small cross-section thus greatly reducing the length of the power cables used.

In addition, contactors:
- are rugged and reliable because they do not contain delicate mechanisms,
- are easily and quickly adapted to the control circuit supply voltage (either the mains or a separate supply),
- after a momentary break in supply, protect personnel against automatic re-start (3 wire control),
- provide easier distribution of emergency stop and interlock stations inhibiting operation of the machine until all precautions have been taken,
- protect the load against large voltage drops (instantaneous opening below a minimum voltage),
- lend themselves to the design of simple or complex automatic control schemes.

CONTACTOR DESIGN

Electromagnet

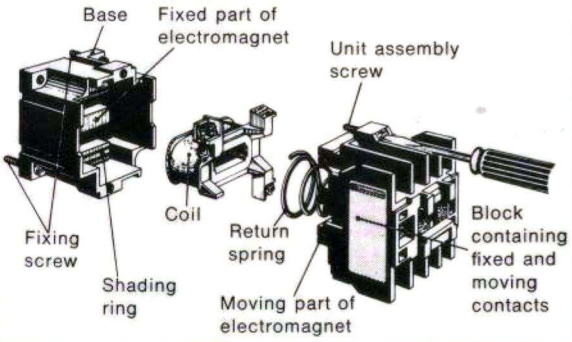
The electromagnet is the driving element of a contactor. It consists mainly of a magnetic core and a coil. Its shape varies as a function of the type of contactor and sometimes depends upon the type of supply, alternating or direct current.
A small gap provided in the magnetic circuit in the closed position eliminates any residual magnetism. The gap is created by the removal of metal or by insertion of a non-magnetic material
In a magnetic circuit armature travel is the distance between the fixed part and the moving part when the contactor is de-energized, whereas the compression travel is the distance between these two parts when the poles come into contact.
The springs which provide the pressure on the poles are compressed during and up to the end of the compression travel.



AC electromagnet (rotation circuit)

1 - Moving part stop
2 - Moving armature
3 - Moving part of the electromagnet
4 - Return spring
5 - Coil
6 - Fixed part of the electromagnet
7 - Shading ring
A - Open position of armature
AC - Air gap
B - Position of armature when poles are in contact
BC - Compression travel distance

a.c. electromagnet (parallel movement)



a.c. MAGNETIC CORES

Characteristics:

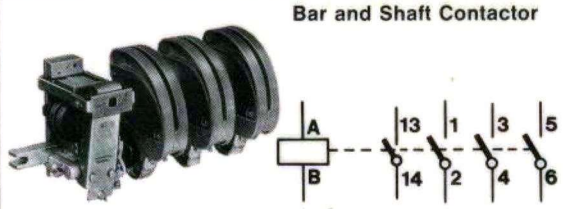
- riveted silicon steel laminations;
- laminated core in order to reduce eddy currents which are created in any metal body subjected to an alternating flux (these eddy currents reduce the useful flux for a given magnetizing current and heat the magnetic core);
- accurate grinding of fixed and moving parts to ensure silent operation;
- one or two shading rings or Frager windings, creating in one part of the core a flux out of phase with the main alternating flux.

This prevents periodic cancellation of the total flux and thus of the attractive force (which would cause chattering).

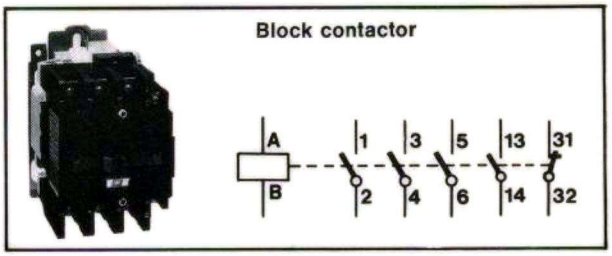
Use on direct current:

A laminated magnetic core can be used without problems with d.c. In this case the coil used is different to that used for an a.c. supply of the same voltage.
In addition, an economy resistor should be inserted in the coil control circuit as soon as the contactor closes (see page 13).

Bar and Shaft Contactor

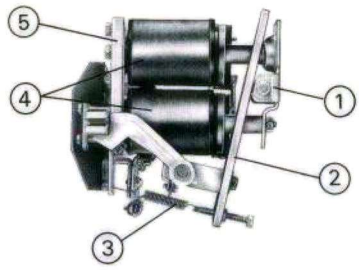


Block contactor



d.c. MAGNETIC CORES

In the magnetic core of an electromagnet supplied with direct current no eddy currents are formed. In some cases, instead of using an "alternating current" type laminated magnetic core with the essential additions, it is preferable to choose a "direct current" type of electromagnet. The core is then usually of solid steel and therefore particularly robust.



Direct current electromagnet

1 - Moving part stop
2 - Moving armature of electromagnet
3 - Return spring
4 - Coils
5 - Fixed part of electromagnet

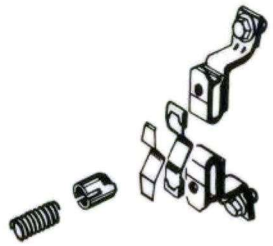
COIL

The coil produces the magnetic flux required to attract the moving armature of the electromagnet: depending upon the type of contactor it is mounted on one or two legs of the magnet. The coil is designed to withstand mechanical shocks caused by the closing and opening of the contactors as well as electromagnetic shocks due to current flow in its turns. In order to reduce mechanical shocks the coil or the core, and sometimes both, are mounted on shock absorbers.
Modern coils are highly resistant to overvoltages, physical shock and corrosive atmospheres; they are made of reinforced enamelled copper wire and some are vacuum impregnated and encapsulated.

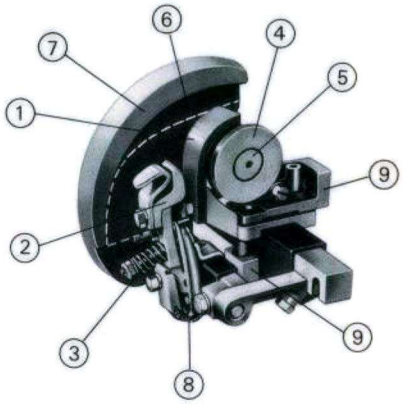
Poles

These are designed to make and break the current in the power circuit. Consequently they are designed to allow the flow of the rated current of the contactor in continuous service without overheating.

They include a fixed part and a moving part, the latter being equipped with springs which transmit a suitable pressure to the contacts. Contacts are of the single-break or double-break type.
Poles are generally fitted with silver cadmium oxide contacts providing high mechanical strength and resistance to welding. They are usually provided with a blowout coil to extinguish the arc (see page 14) which is created between the fixed part and the moving part when the contactor opens under load.
Normally closed poles operate in the reverse manner to normally open poles; with the coil de-energised the normally closed poles conduct.



Contactor double-break pole



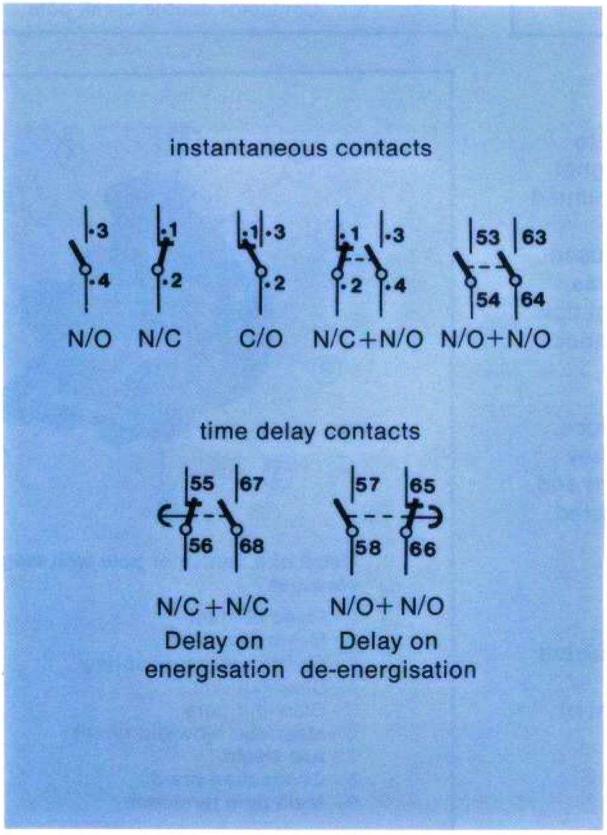
Detail of a contactor pole with magnetic blow-out

1 - Fixed contact
2 - Moving contact
3 - Contact pressure spring
4 - Blow-out coil
5 - Blow-out core
6 - Magnetic blow-out cheek
7 - Arc shield
8 - Connection braid
9 - Main pole terminals

Auxiliary contacts

Auxiliary contacts provide hold-in and sequence interlocking as well as signalling in automatic control equipment. They are available in several versions:

- instantaneous normally open (N/O) conducting when electromagnet is energized;
- instantaneous normally closed (N/C) contact conducting when electromagnet is de-energized;
- instantaneous C/O contacts: in the contactor rest position, one of the contacts is open while the other is closed. When energized the contacts are reversed. The moving bridge is common to both contacts and there are three connecting terminals;
- double instantaneous contacts "N/C + N/O", "N/C + N/O" each contact having its own moving bridge. There is no common point and inputs and outputs are separate (4 terminals);
- time delay contacts "C/O" or "N/C + N/O": the contacts make or break a certain time after opening (de-energisation) or closing (energisation) of the contactor which actuates them.



PERFORMANCE OF A MAGNETIC CIRCUIT ON ALTERNATING AND DIRECT CURRENT

Relationship between attractive force and control current

When the contactor is open and the coil is energized the lines of magnetic flux pass through a wide path in the air and the total reluctance (1) of the magnetic circuit Rma is very high. Therefore a large inrush current is required to create an attractive force greater than that of the return spring and to permit closure:

$$\Phi \; a = \frac{nIa \text{ (high)} \quad (2)}{Rma \text{ (very high)}}$$

When the contactor is in the closed position the magnetic circuit has a very low reluctance Rmf. The attractive force is now very high, since it must balance the force of the pole pressure springs but the corresponding flux Φc can be obtained, due to the low reluctance, with a current much lower than the inrush current:

$$\Phi \; c = \frac{nIf \text{ (low)}}{Rmf \text{ (very low)}}$$

In short, to hold the magnetic circuit closed a current Ic much lower than the inrush current Ia, required for closure, will be sufficient.

Magnetic circuit on alternating current

With alternating current the value of the current in the coil is determined by its impedance (3).
On pull-in, due to the presence of a large air-gap, the reluctance of the magnetic circuit is high and the coil impedance is low (4).
The inrush current Ia is high and is limited almost entirely by the resistance of the coil.

---

(1) Reluctance is the resistance the magnetic circuit offers to the passage of flux; it can be compared to the resistance of an electrical circuit which opposes current flow (Ohm's law).
In a magnetic circuit of soft iron having a length l, uniform cross sectional area A, permeability μ, reluctance is expressed:

$$Rm = \frac{l}{\mu} \times \frac{l}{A}$$

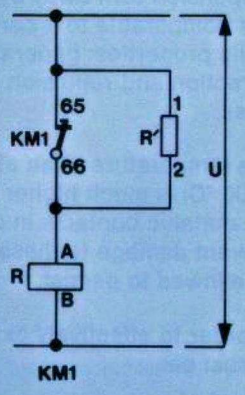
In most cases it amounts to that of the air-gap because the permeability of magnetic metals is much greater than that of air (100 to 1,000 times, depending upon the degree of saturation).

In the closed position the magnetic circuit has a low reluctance and the coil impedance is now high; this high impedance limits the current to a value considerably lower than Ia (for example 6 to 10 times lower).
In short, the current drops for no other reason than the increase in impedance due to the reduction of the air gap.

Magnetic circuit on d.c.

The value of the current is determined only by the resistance of the coil.
On pull-in, the coil resistance allows a current Ia sufficient to close the contactor.
After the armature is closed the current remains equal to the inrush current Ia whereas as we have seen above, a much lower current is sufficient to hold the armature in the closed position.
Except in the case of a specially designed armature the power which results from the continuous flow of inrush current Ia cannot be absorbed for a long time by the coil without an appreciable rise in its temperature. It is therefore necessary to reduce the holding current; this is obtained automatically with alternating current by the change in coil impedance.
On d.c. this power consumption is reduced by inserting an additional resistor R', of an appropriate value, in series with the coil. This resistor is connected in circuit by a normally closed contact across the resistor which opens after the contactor has closed.

use of an economy resistor



On pull-in the inrush current is equal to:

$$Ia = \frac{U}{R}$$

Once the contactor is closed, it becomes:

$$Ic = \frac{U}{R + R'}$$

U: supply voltage
R: coil resistance
R': value of the economy resistor.
This method is very often used when supplying direct current to an "alternating current" type of electromagnet. Of course the coil must be carefully chosen because it is different to the one normally used for the same a.c. supply.
Sometimes coils on a d.c. supply are not equipped with an economy resistor: in these cases the cores are of solid iron and equipped with two coils connected in series. This arrangement permits a considerable increase in power dissipation since the cooling surface of the system is doubled.
This type of "direct current" system is used mainly for the control of contactors subjected to high rates of operation calling for great mechanical durability.

---

(2) The flux is proportional to the ampere-turns but inversely proportional to the reluctance:

$\Phi = \frac{nI}{Rm}$, where I is the coil current and n is the number of coil turns.

The attractive force is proportional to the square of the flux.
(3) For an alternating current of angular frequency ω (314 at a frequency of 50 Hz) and a circuit whose resistance is R, inductance L and capacitance C:
the impedance will have a value of:

$Z = \sqrt{R^2 + X^2}$

with $X = L\omega - \frac{1}{C\omega}$

(4) The impedance of the coil is roughly inversely proportional to the reluctance of the magnetic circuit:

$L = \frac{n^2}{Rm}$, where n is the number of coil turns.

Note: formulae are given without specifying the units which depend upon the system used.

GENERAL CHARACTERISTICS OF THE ELECTRIC ARC

When a contactor opens on load and the moving and fixed contacts separate an arc is drawn. This arc can be defined as a column of ionized air containing electrons and metal molecules in suspension torn away by heat from the contact. It is comparable to a conductor and possesses all its properties: generation of a magnetic field, attraction and repulsion by a magnetic field or mass.

The temperature of an arc, between 5,000 and 8,000 °C, is much higher than the melting point of the metallic contacts in question. In order to prevent damage to these contacts the arc must not be allowed to persist.

In order to effectively extinguish an arc, it must be:

- cooled,
- drawn out beyond the contact zone.

These two methods suffice for the breaking of a.c. currents of up to several hundred amperes or even for the breaking of d.c. currents under certain conditions.

a.c. current is interrupted naturally as it passes through the zero point in the cycle. By making the arc pass over the cold walls of a blow-out chamber the temperature of the ionized air is lowered. This aids the deionization of the inter-contact medium and prevents reignition of the arc.

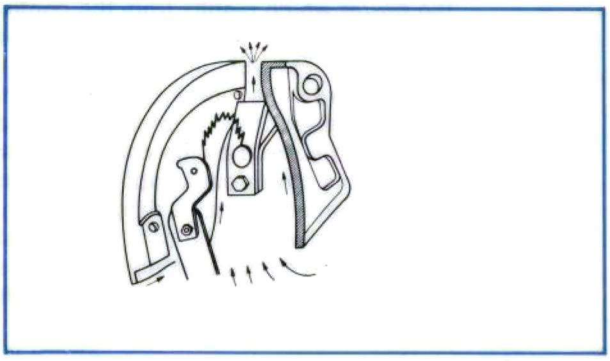
d.c. current does not pass through zero but the insertion of an arc places a new load (the arc) in series with the main load. A voltage drop appears across the terminals during the current flow. This voltage drop or "arc voltage" Ua increases if the arc is lengthened (while its cross section is reduced) and if its temperature decreases (the arc resistance increases).

This increase in resistance, the modification of the dielectric by lowering the temperature and the turbulence of the ionized medium contribute to the extinction of the arc.

We shall first examine the usual devices used to draw out on arc and to cool it. We shall then consider a few details concerning the characteristics of the arc voltage and the phenomenon of breaking a direct current before describing the blow-out device.

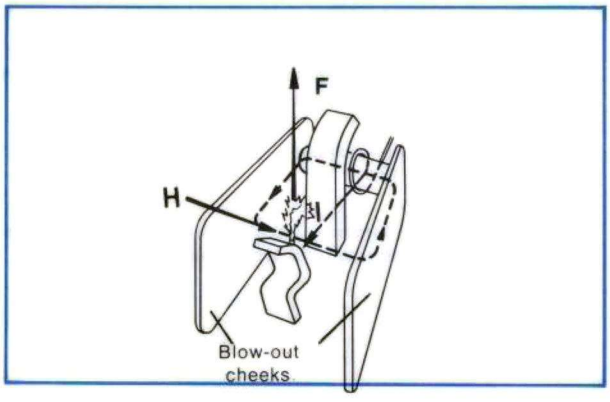
Blow-out by self-ventilation

Each of the contactor poles is covered by an insulated arc shield open wide at the bottom and reduced to a slit at the top. This design feature creates a draught comparable to the up-draught produced by a chimney. When the arc is set up between the contacts it heats the air contained in the chamber. This heated air rises and escapes through the slit provided at the top and it is immediately replaced by cool air introduced at the bottom. Pulled upward by this draught, the arc lengthens, cools as it passes over the metal pieces and is finally extinguished.
When the breaking current is too great, blow-out by self-ventilation is insufficient in which case a magnetic blow-out is required.



Magnetic blow out

This blow-out device includes:
- a coil whose turns, wound around a mild steel core, are connected in series with the fixed part of the pole and through which flows the current drawn by the load;
- two sideplates of an insulating material;
- two magnetic steel cheeks fixed to the sideplates.



When the contactor is closed the blow-out, through which the main current flows, creates a magnetic field proportional to the number of turns and to the current flow (blow-out ampere-turns). This field is channelled by the two steel cheeks towards the area of the chamber in which the arc should be extinguished.

In this area the magnetic field produced by the blow-out coil and the arc which is set up are perpendicular and the coil is wound in such a direction that the arc is deflected upward within the chamber.

The direction of displacement is confirmed by Flemings Right Hand rule.

The suction due to the special shape of the blow out chamber adds to the electrodynamic effect to further increase the efficiency of the device. With a.c. the passage through zero aids the extinction of the arc.

It should be noted that with alternating flux induced currents are created in the body of the magnetic core, reducing the value of the blow-out field and causing a phase shift with respect to the current. To overcome this problem the cores are laminated when the frequency is higher than the customary industrial frequencies.

Magnetic blow outs can be used with d.c. as well as with a.c. since the reversal of the direction of current flow in the pole reverses that of the field and the direction of the force acting upon the arc remains unchanged.

However, since there is no passage through zero the number of turns of the blow-out coil is inversely proportional to the current to be controlled.

In any case it is essential to produce a field sufficient to lengthen the arc, to deflect it towards the top of the shields and to extinguish it within a certain time, because:
- if too much time is taken to extinguish the arc the conducting parts will wear out prematurely;
- if the arc is extinguished too quickly a voltage surge is produced in the circuit which might cause a breakdown of the insulating material especially when used in an inductive circuit.

Arc voltage characteristics

The electric arc is very complex so we shall briefly analyse some features of the arc voltage. Let us imagine an arc being set up between the fixed and moving parts of a pole called anode and cathode respectively.

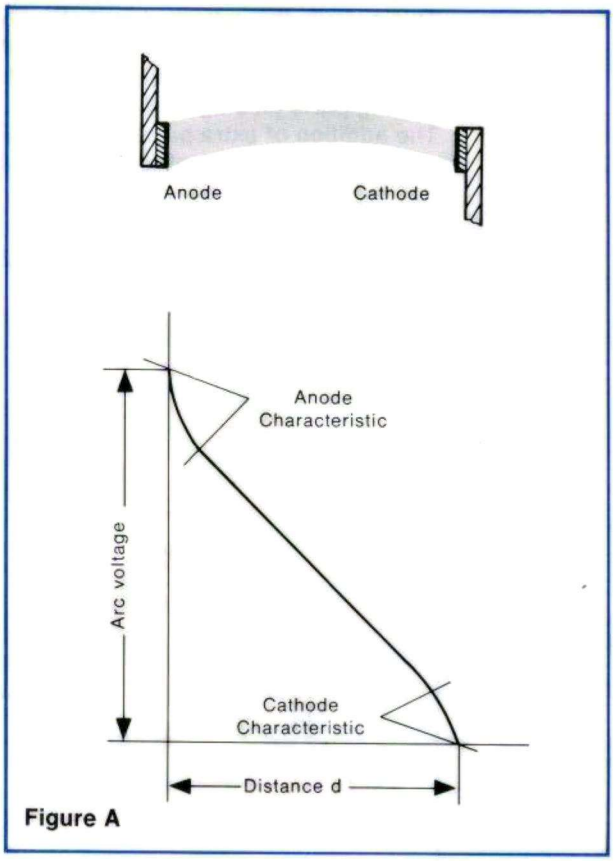
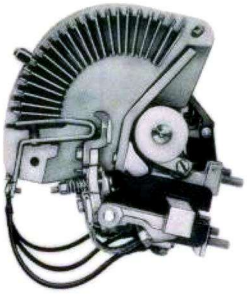


Figure A

For a given contact separation distance it will be seen in figure A that at the two ends the voltage decreases rapidly whereas in the middle part it decreases linearly as a function of the distance. In brief this curve shows three distinct characteristics:
- an "anode" voltage drop (high);
- a linear voltage drop as a function of the contact separation distance (low);
- a cathode voltage drop (high).

If a metal piece is inserted in the arc path a new anode as well as a new cathode will be artificially created.



This permits the voltage drop between the two contact points to be increased but without increasing the distance between the fixed and moving parts (see figure B).
The addition of extra pieces called splitters, in the arc shield, takes advantage of this and also aids arc cooling (see figure C).

In some particular cases (high voltage, certain d.c. applications, etc.) the use of contacts in series or the addition of splitter type arc shields or a combination of the two methods is used.

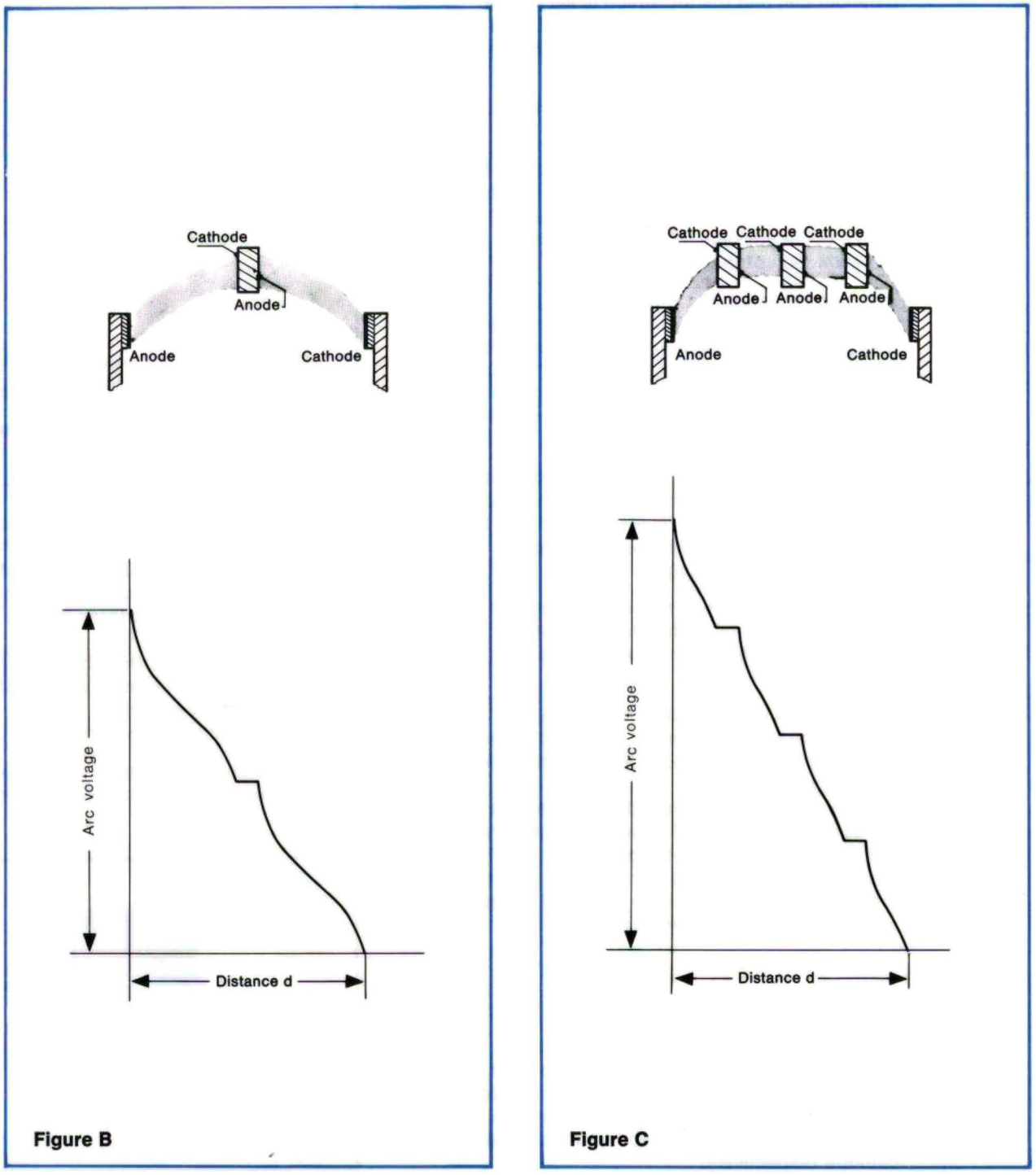


Figure B

Figure C

CONTACTOR SELECTION

The choice of a contactor depends upon:
— the type and voltage of the main supply,
— the load characteristics,
— the duty requirements,
— the standards required by certain organizations (Veritas, Lloyd, Merchant Marine...) or by eventual users.

This implies a knowledge of various characteristics of the contactor such as:
— rated operating voltage,
— rated operating current,
— maximum thermal current,
— utilization category (example: AC1 - Resistive circuits; AC3 - Starting of squirrel cage motor, breaking running current),
— nature and special characteristics of transient phenomena related to the load circuit (capacitance, inductance, etc.) more especially during contactor opening and closing.

In addition the electrical endurance or life of the poles must be taken into account and sometimes environment, temperature and altitude must be considered.

It is not always necessary to consider all of these criteria in order to determine the rating of a contactor but in order to help the reader make a correct choice several of the most common examples are described below.

Selection of a contactor for a distribution circuit

This concerns the transmission of current without heating the contactor poles and terminals above permissible limits so the busbars and feeders must be adequately rated.

In a distribution circuit the contactor can be used:
• either as a line contactor sometimes of a high-breaking capacity type and associated with instantaneous protection devices (HRC fuses, high speed protection relays, etc.). Service life is long and the number of operations is low. The contactor in most cases closes under no load and opens under normal load.

• or as a feeder contactor:
The contactor, located on the load side of the main disconnecting device, is used to supply branch circuits.

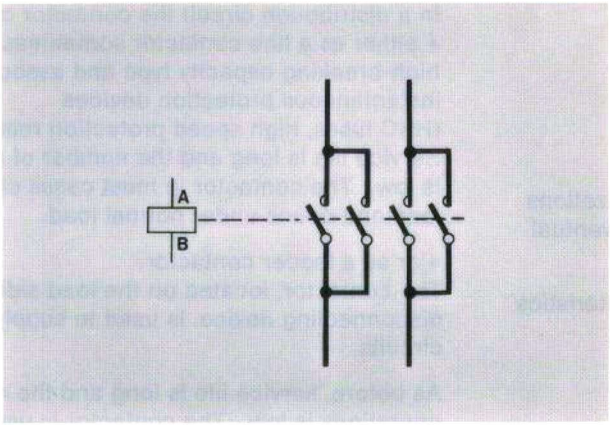
As before, service life is long and the number of operations is low. The contactor is usually closed and opened under no-load conditions so cos φ is immaterial; only the thermal rating need be considered.

Selection of a contactor for a heating circuit

This use falls under category AC1 (see page 196): furnace switching, industrial heating, drying, domestic heating, swimming pools, tanks, etc.
— Requires few operations.
— On-load breaking.
— Only thermal rating need be considered because cos φ is close to 1.
— Since the apparatus is usually mounted in an enclosure, internal temperature must be taken into account; that is, 55 to 60 °C around the contactor for a room temperature of about 40 °C.

With a single phase supply a four pole contactor may be used with two poles connected in parallel for each line.

In this case, since current flow is not necessarily distributed equally between the two poles, a reduction factor of 0.8 should be applied to the permissable thermal rating.



Selection of a contactor for control of a lighting circuit (incandescent lamps)

— Use requires few operations.
— Only thermal rating need be taken into account since cos φ is close to 1.
— A current peak which can be 15 to 20 times In, occurs when the circuit is closed (cold and low-resistance filaments).

Thus the contactor must be able to make this peak current and as before a four-pole contactor can be used with two poles connected in parallel in each line.

Selection of a contactor for control of a lighting circuit (mercury-vapour, sodium-vapour and halogen lamps without compensation)

— Use requires few operations.
— Thermal rating alone can no longer be taken into account because cos φ is 0.5; this involves an inductive circuit in which a large arc will be produced at the moment of breaking.
— Peak making current is not high: 1 to 1.6 In.

A four pole contactor can be used with two poles connected in parallel in each line.

Selection of a contactor for control of a lighting circuit (fluorescent, mercury-vapour, sodium-vapour and halogen lamps with power factor correction)

— Use requires few operations.
— The addition of capacitors improves cos φ which changes from 0.5 to 1.
— On the other hand when the circuit is closed, a peak current of the order of 15 to 20 In appears and care must be taken to select a contactor capable of making this peak current.

Selection of a contactor for switching a transformer primary

This use depends first of all upon the type of load connected to the secondary.

However, when power is applied to the primary, the peak magnetising current can reach 25 to 30 times the rated current and it lasts for a half-cycle. This must be taken into account when determining the protective fuse rating and the size of the contactor.

Selection of a contactor for the coupling of capacitors

The connection of capacitors used to improve the power factor of an installation presents the following problems:

— when switched into the circuit the capacitors, which are completely discharged, draw a current which corresponds practically to a short circuit current limited only by the impedance of the line and transformer.

If the circuit contains capacitors already connected an additional current due to their partial discharge is added to the previously mentioned brief but very high peak current.

This additional current is even higher when the power factor is corrected automatically in cascade, especially for the last contactor. When the current peak may disturb the supply feeder it can be limited by inserting into the circuit, for a fraction of a cycle, either inductors or resistors which are then shunted by a contactor.

— In steady state operation, in addition to the rated current input to the capacitor bank, harmonic currents flow in the circuit. Having a mainly thermal effect these currents should be taken into consideration when selecting the size of the contactor.

— To aid the discharge of the capacitors, when they are switched out of the circuit, and to prevent phase shift during later switching operations resistors are automatically connected across the terminals of the bank by means of the contactor as soon as it opens.

Selection of a contactor for squirrel cage or slipring induction motors (breaking load during normal running at rated speed)

Operations fall under the following categories of utilization:

- for slipring motors: AC'2 according to the UTE standard or AC2 according to the VDE, IEC and BS standards;
- for squirrel cage motors: AC3 (see page 197).

— Use involves a large number of operations.
— With the duty identical, breaking occuring when the motor is running, the duty categories AC2/AC'2 and AC3 can overlap. It is not necessary to take into account the peak starting current because it will always be less than the breaking capacity of the contactor.
N.B.: In the case of long and repeated starts heating of the poles should be taken into account.

— Contactors selected for the above duties can withstand 0.5% of operations with the motor stalled (inching*, i.e. utilization category AC4).

Selection of a contactor for squirrel cage or slipring induction motors (breaking during starting)

This involves the following utilization categories:

- for slipring motors: AC2 according to IEC and UTE standards, AC2' according to VDE ;
- for squirrel cage motors: AC4 (see page 197).

— Use involves a large number of operations.
— Breaking current is high.
— On each break the arc drawn between the contacts destroys a small amount of their surface and wear is more rapid.
To obtain a certain electrical life or service life** a contactor of higher rating may be required.

* Very brief energization of the motor, for example inching operation. Since the motor current is broken during starting the current broken is higher than when breaking with the motor running at its rated speed.

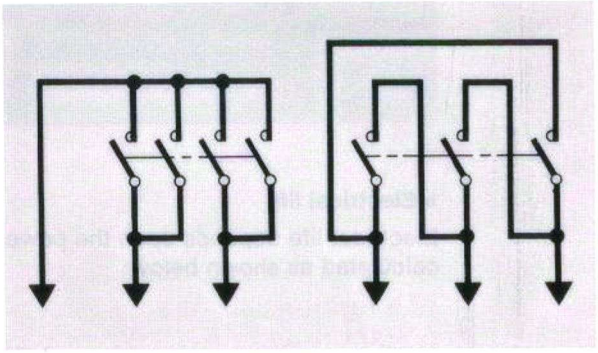
** Service life of a contactor

$$= \frac{\text{electrical life as a function of the current broken}}{\text{number of operations per hour} \times \text{number of hours worked per month} \times \text{number of months worked in a year}}$$

Example: $\frac{2{,}200{,}000}{50 \times 200 \times 11} = 20$ years.

Selection of a contactor for short circuiting of rotor resistances

— This application represents a light making and breaking duty.
— Only the thermal effect of the current need be taken into account.
— When there are several short circuiting contactors those controlling all steps but the last have a lower duty factor (in this case the duty factor is the ratio of the time the contactor in question carries current to the interval of time between two consecutive starts, see page 196). For this reason the current flowing for a limited time can be higher than the current that the contactor could withstand in continuous service.
— Four pole contactors can be used to virtually double the current permitted in double pole short circuiting. By delta connecting the poles of a triple pole contactor the current per pole is reduced to $\frac{1}{\sqrt{3}}$ of the phase current.



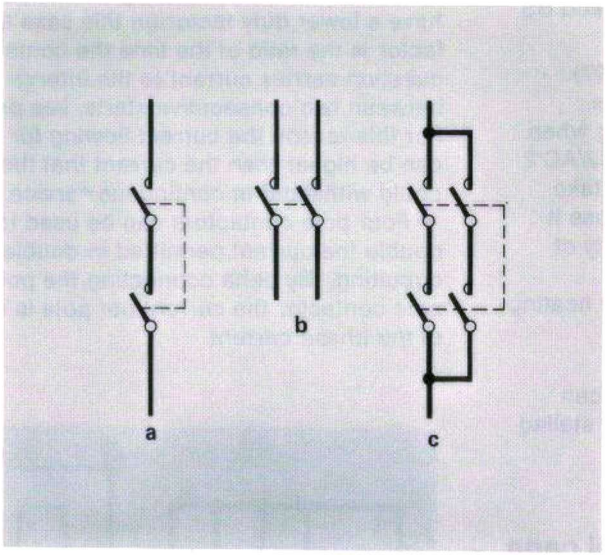
Selection of a contactor for d.c. switching

With d.c. supplies not only the size of the contactor but also the number of poles to be connected in series must be considered.
The points to be considered are as follows:
— voltage,
— current to be broken,
— electrical life required,
— type of load and in particular the time constant $\frac{L}{R}$

- **Contactor selection**

— The number of poles to be connected in series, for a given application, depends upon the type of contactor. Refer to the selection tables.

— Poles n series can be connected in one line (schematic a) or in both lines (schematic b).
The size of the contactor which determines the rated current Ie should be defined as a function of the current I flowing in the circuit:
— poles in series only: Ie $\geqslant$ I (schematic a)
— if each pole in series is replaced by n poles in parallel: n Ie x 0.8 $\geqslant$ I (schematic c).



• **Electrical life**

Electrical life depends upon the power broken calculated as shown below:

Type of load	Recovery voltage Ur	Power broken Pc
Resistance, electromagnet or motor with breaking at slow speed under full voltage	Ur = Ue Back emf of circuit negligible	I broken x Ue
Switching while running or Ward-Leonard drive	Ur < Ue High back emf	I broken x 0.5 Ue
Motor with breaking during reverse current braking	Ur > Ue Back emf opposed to supply voltage	I broken x 1.5 Ue

The desired electrical life can be obtained either by increasing the number of poles in series or in parallel or by increasing the size of the contactor.

FACTORS LEADING TO CONTACT DETERIORATION

When contact burning is noticed a check should be made to see if the rating of the contactor corresponds to the power of the motor. If the rating is correct and particularly if the stalled motor current is less than the making capacity of the contactor the damage is usually the result of problems in the control circuit which lead to poor operation of the electromagnet.

We shall indicate the most frequent problems and the recommended solution for each of them.

Mains voltage drop

• **Voltage drop** caused by the peak motor starting current at the moment the moving contacts touch the fixed contacts.

This voltage drop causes a loss of energy in the armature which then does not have the force to completely close the contacts.

With no pressure on the poles burning occurs and when the motor has reached its rated speed the voltage increases; at around 85% of Un the armature closes completely. In this case the installation is at fault so the lengths and cross-sections of the cables and supply transformer capacity should be checked.

• **After a mains failure,** when the voltage is restored the cumulative peak current created by the simultaneous re-starting of several motors can cause a voltage drop.

In this case, in order to reduce this voltage drop, the scheme must include sequential re-starting.

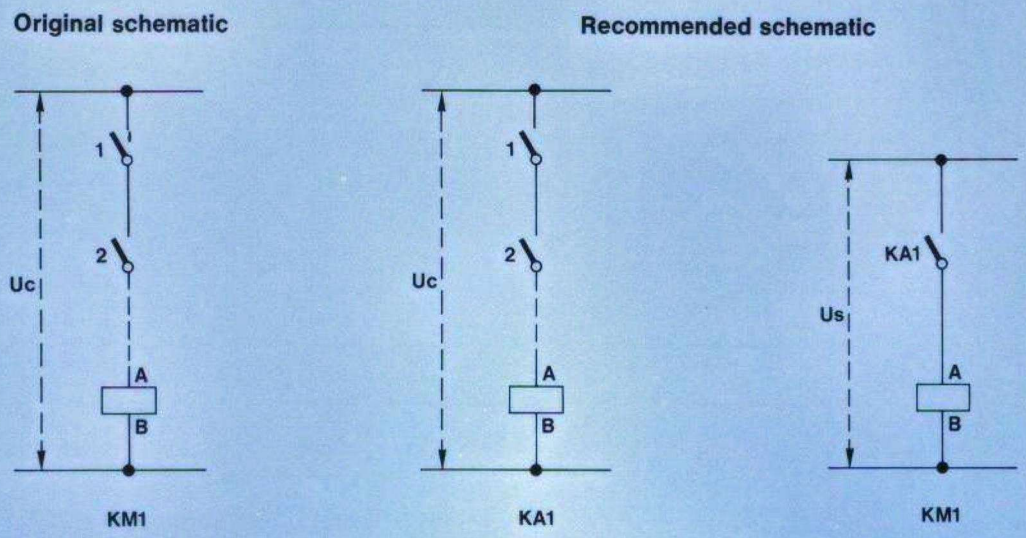
Voltage drop in the control circuit

When the contactor is supplied with low voltage (24 to 110 V) and a number of control contacts are in series a voltage drop in the control circuit can occur at the moment the contactor pulls in.

This voltage drop is added to the one caused by the motor starting peak and the situation is the same as the one previously described.

In this case the contactor in question should be supplemented by an interposing relay, whose inrush current is less, which will control the main contactor coil.

VOLTAGE DROP IN THE CONTROL CIRCUIT



Uc = control voltage
Us = mains supply voltage

Vibration of control contacts

In a sequence control system contacts can vibrate or chatter (thermostat, pressure switch, etc.). These vibrations can have an effect on the electromagnet of the contactor causing incomplete closure and possibly the welding of poles.
The solution is to introduce a time delay of the order of two to three seconds by using a timing relay with delay on energization.

Transient mains failure

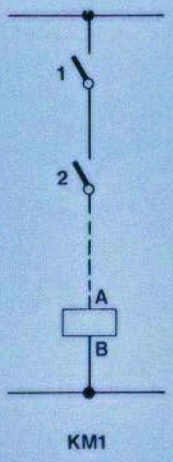
Upon reclosure of the contactor after a dip in the mains voltage (a few milliseconds) the back emf of the motor is no longer in phase with that of the mains supply; in this case the peak current can reach twice the rated peak. Poles risk being burned when the making capacity is exceeded.
To prevent this problem the reclosure of the contactor should be delayed by two to three seconds by means of a timing relay with delay on energization.
To protect contactors against transient mains failure it is also possible to prevent the contactor from opening by the use of an opening delay timer such as type NY1 R manufactured by Telemecanique.

Consequences

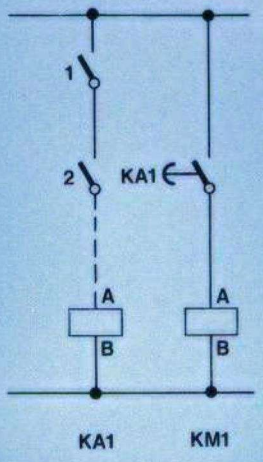
If poles weld and the operating coil is de-energised the contactor is "suspended" on the welded poles and the non-welded poles will break but only for a limited distance.
A short arc is set up and burning occurs eventually destroying the contact and possibly igniting surrounding material. On contactor analysis it is often observed that one or two poles are intact; these are the ones which were welded.
It should be noted that the current is not higher than the rated motor current so the protection devices will not act until the component is destroyed and a short circuit occurs.

VIBRATION OF CONTROL CONTACTS - TRANSIENT MAINS FAILURE - INCHING

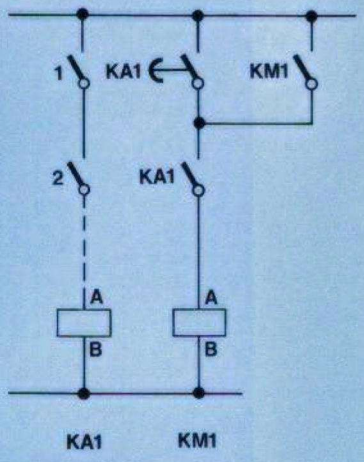
Original schematic



Recommended schematic



Small contactor

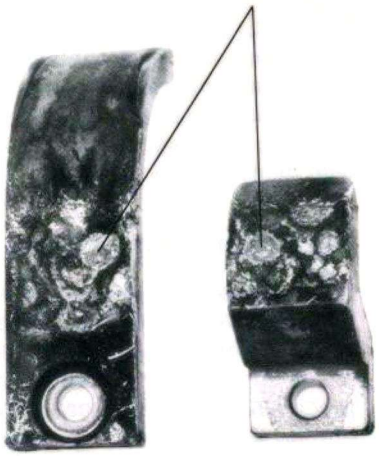


Large contactor

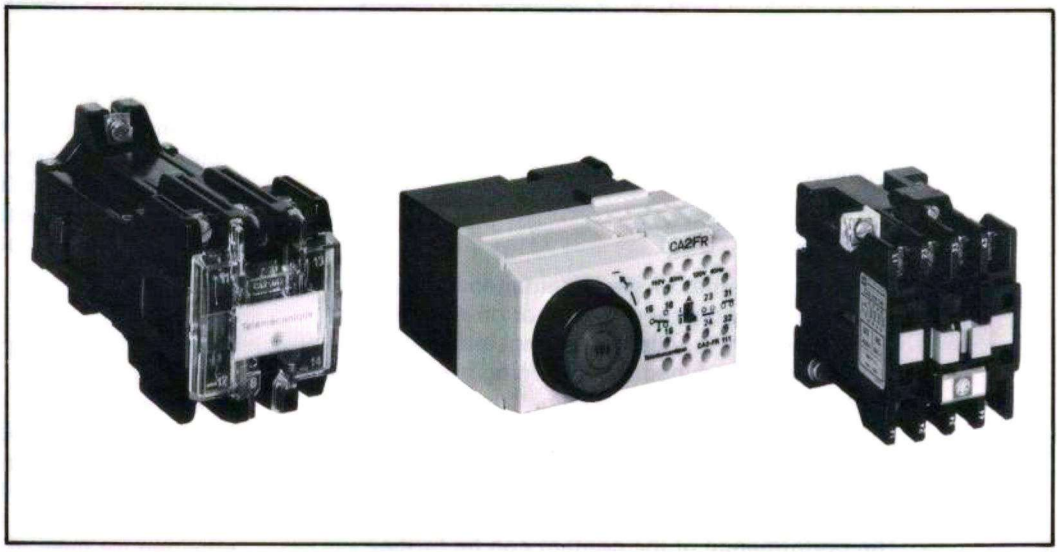
Conclusion:

The troubles which can cause the welding of contactor poles are very difficult to record due to their short duration and infrequent occurrence. Moreover these incidents do not always occur systematically on each closure of the contactor but generally appear when there are several simultaneous problems or when trouble occurs on a supply line whose voltage is already near the minimum permissible value.
The contactor is not at fault. It is therefore pointless to change the product, for example by choosing a larger size, but it is essential to redesign the control circuit to eliminate the cause of the failure.

Weld points



Essential elements in any control scheme, control relays are used extensively with contactor gear. They provide a number of functions such as circuit selection, sequence control, safety, signalling, etc.
These devices are designed to switch low currents but they must be reliable since the correct operation of the control equipment depends upon their reliability.
Consequently their required mechanical and electrical life is even longer than that for contactors.
On some relays it is possible to change the coil, convert a normally closed contact to a normally open contact or vice versa, add instantaneous or time delay auxiliary blocks or add power poles; on others the coil cannot be changed and the initial contact configuration cannot be modified.



control relays

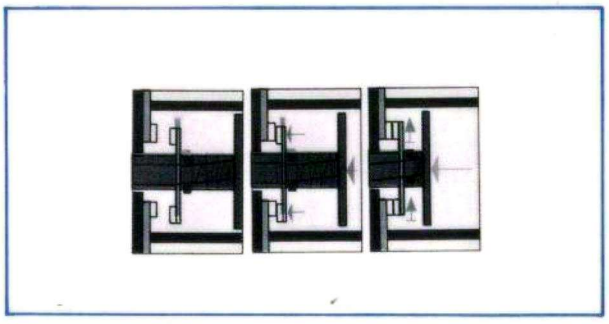
COMPOSITION OF A CONTROL RELAY

Electromagnet

Its operating principle is the same as that of the contactor. The armature is designed according to the type of supply, alternating current or direct current. However some circuits designed to operate on a.c. can be used on d.c. provided that the coil is derated and an economy resistor (see page 13) is inserted in the circuit.
Since the armature of a control relay is usually smaller than that of a contactor the use of special steels reducing eddy currents makes it possible to design a.c. solid cores
On d.c. the system designed to prevent residual magnetism normally consists of a non-magnetic strip. This solution as well as the use of a solid core with a.c. permits mechanical life to be increased considerably.

Contacts

Contacts are either of the instantaneous type or with time delay on energization or de-energization. Complementary functions (fleeting, latching, flashing) are produced by combining armatures or by means of electronic circuits.
Since the contacts can be used to break inductive loads or to ensure switching of low level signals the material of the contact tips is selected with these two criteria in mind.
The performance of the contact can be further improved by causing the moving part to slide over the fixed part (self wiping) or by serrating the contact tips (multiplication of the points of contact).



SELECTION OF A CONTROL RELAY

The choice depends upon the overall dimensions and design and operation of the equipment. Telemecanique offers three ranges which although suitable for the same application provide three different designs.

CA2-A
— convertible
— adaptable
— multiple composition
— large variety of uses
Recommended for users who wish to be able to change coil and contacts to obtain many combinations (reduction of stock levels) and want visible contacts and wiring on the same plane.

CA2-D
— compact in size
— composition can be varied instantly using "clip-on" auxiliary blocks
— compatible with D-range contactors.
These units are ideal for compact design and modifications may be made by adding auxiliary blocks.

CA2-F
— monoblock design
— compact
— economical.
Ideal for use in compact equipment this unit is of good appearance and provides safety for personnel (live parts are inaccessible). Connections on the front are on the same level and test points are provided for ease of testing.

We shall examine in this chapter various methods which can be used to solve the problems of protection and compare them technically so as to aid the selection of the ideal solution.

The various types of protection used in automatic contactor equipment are as follows:

- **Protection against small and sustained overloads - thermal overload relays; thermal magnetic relays; thermistor probes.**
- **Protection against large overloads - thermal magnetic relays; electromagnetic relays.**
- **Protection against short circuits - fuses; high-breaking capacity contactors with relay fitted.**
- **Protection against single phasing - thermal differential relays; isolators equipped with striker fuses.**
- **Protection of personnel against accidental contact - isolators.**
- **Supply failure protection - contactors with maintaining contact; voltage measuring relays.**
- **Current overload protection - current measuring relays.**
- **Under current protection - current measuring relay.**
- **Protection against too long or too frequent starting - thermal time delay relays.**

GENERAL

Any load can be the cause of a certain number of mechanical or electrical problems. So that these do not cause damage to the load or to the control gear and cause disturbance of the mains supply these problems must be detected. This is the function of protection relays and fuses, etc.

Among the most frequent incidents involvinga motor are:

- Incidents of mechanical origin:

— Stalling; momentary or sustained overload which leads systematically to an increase in motor current along with a dangerous heating of the armature windings.

When the overload persists the motor is damaged and if the supply cables are matched to the current and duty of the motor they also heat, insulating materials melt and there is a risk of fire.

- Incidents of electrical origin:

— Overvoltage, voltage drop, phase imbalance, phase failure.

— Short circuits whose current can exceed the breaking capacity of the contactor.

In conclusion, when an overload or short circuit occurs a protection device should:

— Protect the line.

— Protect the switching component (for example the contactor).

— Protect itself or be associated with a device which can protect itself.

If the load is a motor :

— Allow it to start taking into account the starting current.

— Protect the motor by inhibiting its operation over too long a period with a current greater than its rated current.

protection against overloads

THERMAL OVERLOAD RELAYS

These relays, designed for use on a.c. or d.c. supplies, provide thermal protection against small and sustained overloads.
Thermal overload relays manufactured by Telemecanique are:

- **Triple pole:**
Used on single, 2 and 3 phase systems.

- **Temperature compensated:**
Unaffected by ambient temperature variations within specified limits.

- **Differential:**
Capable of detecting a phase imbalance or failure thus providing single phasing protection i.e. if a fuse blows.

- **Graduated in "motor current":**
The current setting on each relay is graduated in actual motor load.

PRINCIPLE OF A TRIPLE POLE THERMAL RELAY

Each relay contains three bimetallic elements consisting of Invar and ferronickel having different coefficients of expansion. Each element is fitted with a winding connected in series with each phase of the motor and with a cross-section adapted to the control current; when heated the element bends. When an incident occurs the current to the load increases bending the elements and actuating the differential device whose lateral or vertical displacement, depending upon the relay model, rotates a cam or shaft connected to the triggering device. When the movement is sufficient the piece to which the moving parts of the contacts are fixed moves away from the holding stop causing the opening of the trip contact in the contactor coil circuit and the closing of the signal contact.
The relay cannot be reset until the elements have cooled sufficiently.
The distance that must be travelled to escape the holding stop is a function of the tripping current set on the relay and of the ambient temperature; this requires a correction by the bimetal compensation element.

Compensation as a function of ambient temperature

A bimetal compensation element, independent of the main elements and subjected only to the temperature of the ambient air, bends as a function of the variation in this temperature.
Mounted opposite the main elements, the compensation element balances the bending of the main strips. For this reason the displacement of the thermal elements required to trigger the relay is the same for temperatures between — 20 and + 70 °.

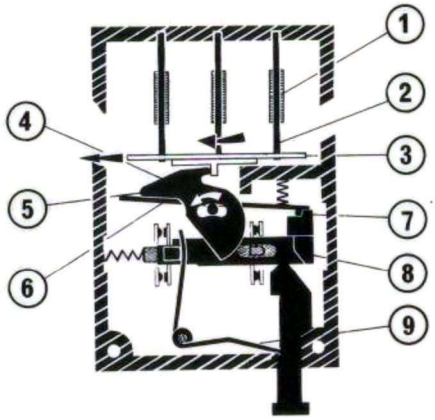


Figure 1

When a high current flows through the heater windings (1) the main elements (2) bend and the differential bars (3) are moved in the direction of the arrow. The cam (4) is also driven and turns on its shaft. The leading edge of this cam (5) causes the compensation strip to rotate (6); the holding stop (7) is released allowing the escape of the movable piece (8) which is pulled by a spring (9). The contacts change position.
In this illustration the relay is in the "set" position, ready to be tripped.

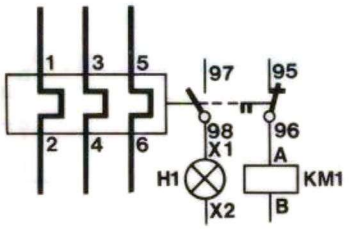
Differential device (see fig. 2)

The differential device causes the relay to trip when the currents flowing through the 3 elements are not identical (unbalanced mains supply, single phasing). The higher the difference, the faster the tripping.
The system includes two differential elements whose movement, tied to that of the elements, controls their displacement. This displacement is relayed through one or two levers to the relay tripping device.
Thermal overload relays equipped with a differential device should not be used on unbalanced supplies, for instance three phase circuits supplying single phase loads.
In this case the placing of two bimetallic strips in series cancels the effect of the differential (see page 28). To overcome this problem Telemecanique also produces non-differential relays.

Setting device (see fig. 1)

The unit is set by moving a cam or setting knob to modify the angular travel of the end of the bimetal compensation element (6) or the lever attached to it in order to escape the latching device (7) which keeps the relay set.
The setting plate is graduated in motor current. The tripping current is between 1.05 and 1.20 times this current which is defined by international standards. The current is set by a lever which moves notch-by-notch along the reference scale.

WIRING DIAGRAMS



Pilot light and contactor coil

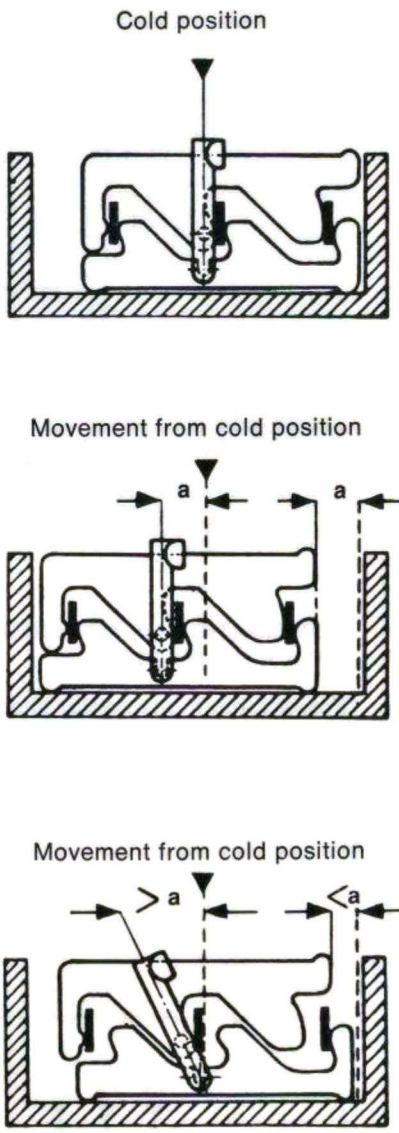
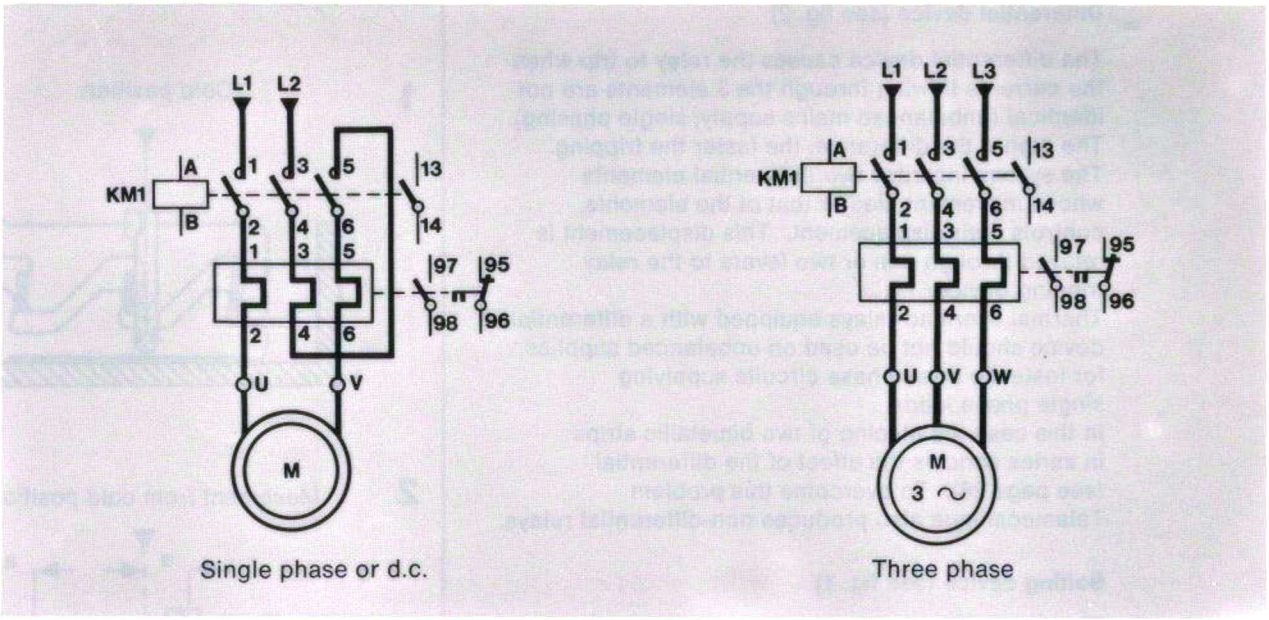


Figure 2

1) cold position - differential elements are to the extreme right.
2) hot position - current is identical in the three bimetallic elements (balanced operation), identical displacement takes place.
3) different currents cause unequal bending of the bimetallic elements ; one moves only a short distance and holds the lower part of the lever. The upper part of the lever, pulled by the other bimetallic elements and the upper differential element moves a greater distance. Tripping of the relay is accelerated.

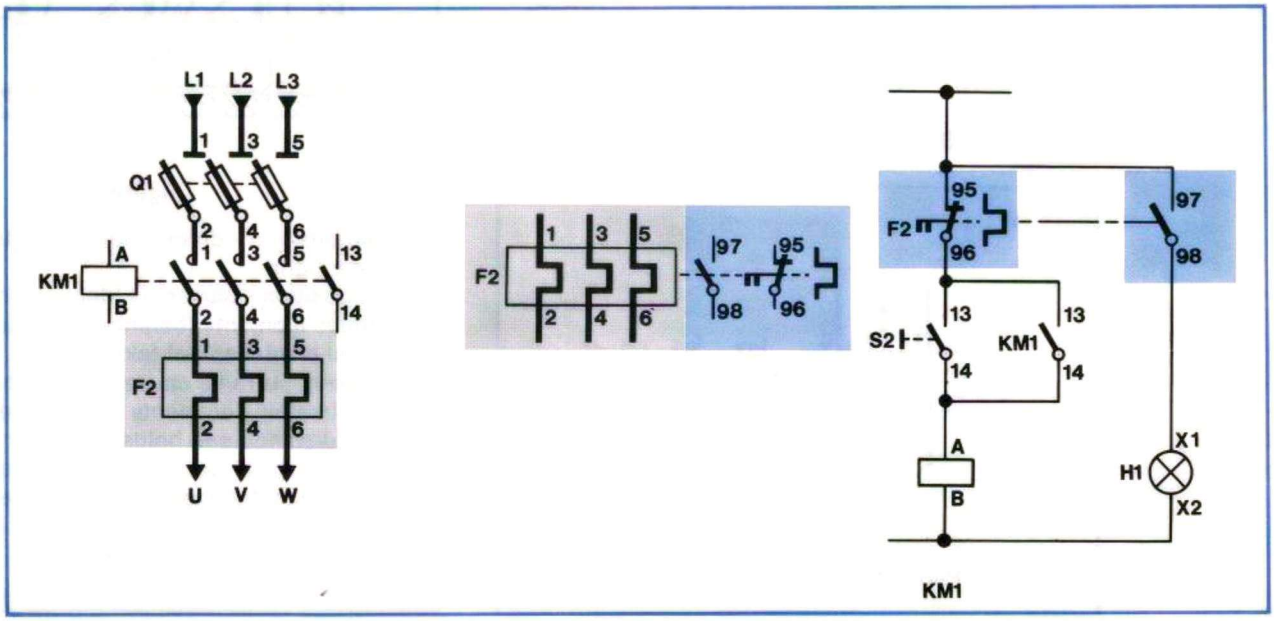


COMBINATION OF A THERMAL RELAY WITH A CONTACTOR

Power circuit: one heater should be inserted in each of the three phases of the load to be protected.
Control circuit: the trip contact of the relay should be connected in series with the coil of the contactor.

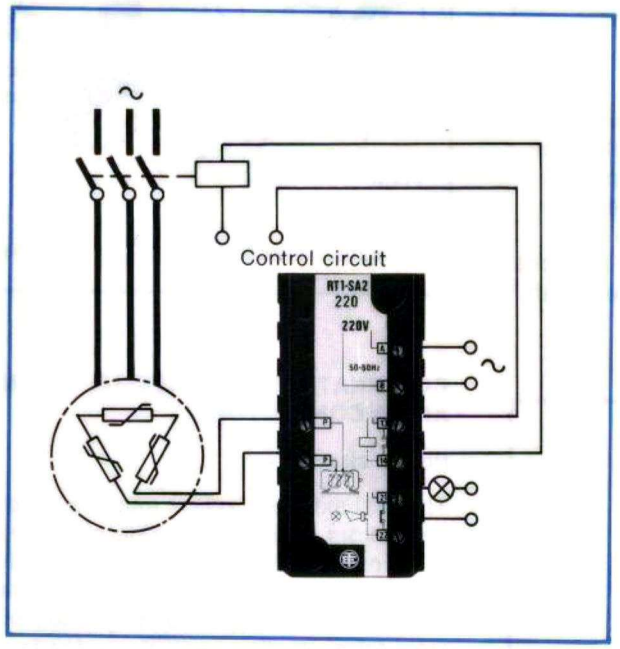
ASSOCIATION WITH FUSES

These overload relays should be associated with fuses which protect against short circuits.
Designed especially for this use "motor-type" fuses protect the motor and equipment against high overcurrents exceeding the breaking capacity of the contactor.
Their size, which should be chosen in relation to the overload relay, is indicated on the relay rating plate.



PTC THERMISTOR RELAY

This protection system takes into account the actual temperature of the motor winding and includes:
— positive temperature coefficient (PTC) thermistor probes embedded in the stator winding of the motor whose resistance varies with temperature;
— a Telemecanique control relay which is sensitive to variations in the resistance of the probes and thus to heating of the motor winding.
The motor is therefore protected against heating, whatever the cause: overload, ventilation defect, ambient temperature too high and under certain conditions locking of the rotor.
In the latter case the temperature of the winding rises quite rapidly; the heating of the probes follows that of the windings with a certain delay which depends upon the size of the probes and how well they are installed in the winding. The speed at which the temperature rises in the stator winding of a motor whose rotor is locked depends upon the current density in the conductors of the winding so that motors are effectively protected by this system provided that the probes are correctly installed.



Applications

All motors for which protection by current measurement is insufficient or impossible:
— frequent starting,
— long starting times,
— frequent small overloads,
— etc.
This device can also provide protection against over heating of any equipment in which a PTC thermistor probe can be installed: bearings, oil baths, gear housings, etc.

Notes

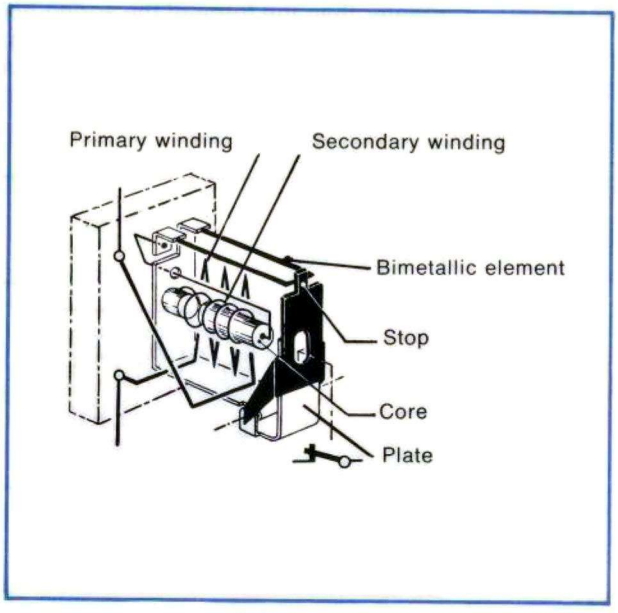
The installation should also include circuit protection, for example a thermal overload relay.

THERMAL MAGNETIC RELAYS

These relays are designed to protect a.c. or d.c. motors against overloads. They will trip after a certain delay for small overloads and instantaneously for high overcurrents.

PRINCIPLE OF ALTERNATING CURRENT THERMAL MAGNETIC OVERLOAD RELAYS

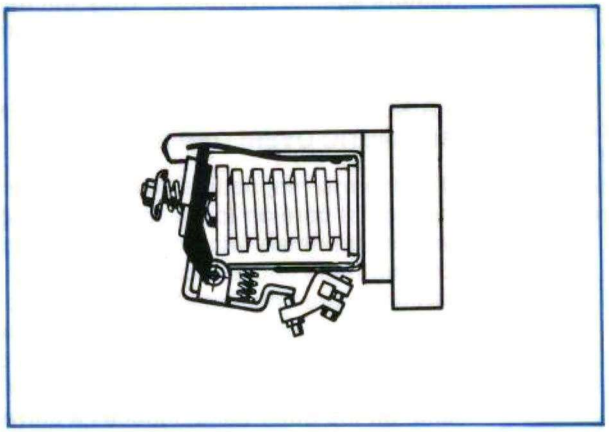
The thermal magnetic element consists of a horizontal core on to which two windings are wound: a primary winding through which the load current flows and a secondary winding whose terminals are connected to a bimetallic strip.
Operation is as follows: the current flowing through the primary winding creates a field which on the one hand tends to attract the plate towards the core and, on the other hand, induces a current in the secondary winding which heats the bimetallic element.



This relay in fact operates like a small transformer and cannot be used therefore on direct current. Depending upon the type of overload two types of tripping are possible:

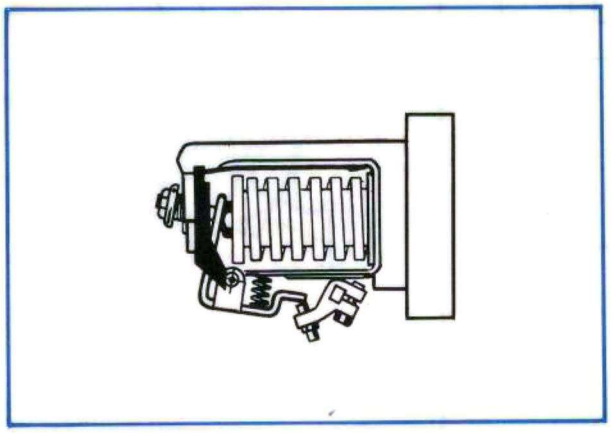
Delayed thermal tripping:

If the current exceeds the set value, the bimetallic element heats, bends and after a certain time releases the stop.
The plate-stop assembly tips and the lever arm, acting on the transmission shaft, causes the contact to open.
The relay cannot be reset until the bimetallic element has cooled sufficiently.



Instantaneous magnetic tripping:

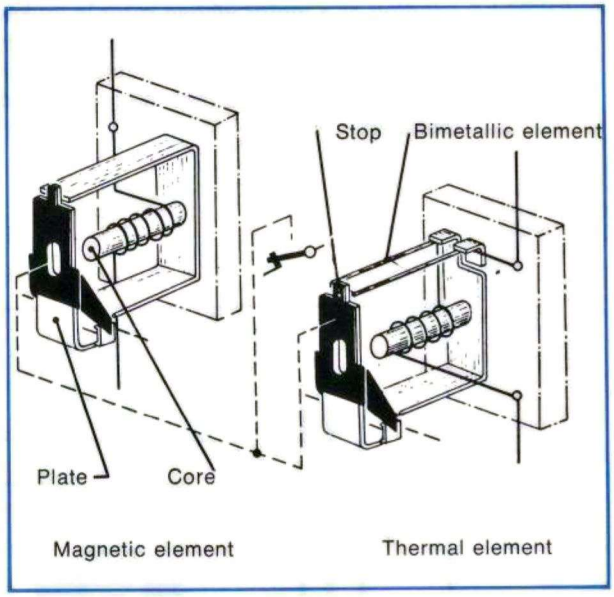
If a high current (greater than 10 x the nominal rating) flows rapidly, before the bimetallic element has time to bend enough to release the stop, the magnetic forces exerted on the plate become greater than the force of the spring holding it against the stop; the plate is pulled against the core and the lever arm, acting on the transmission shaft, causes the contact to open.



PRINCIPLE OF A DIRECT CURRENT THERMAL MAGNETIC OVERLOAD RELAY

The relay contains two different elements:
- a magnetic element similar to the one used for alternating current but there is no secondary winding;
- a thermal element of different design: the bimetallic element is connected directly in series with a winding through which the current flows.

For high currents a shunt is included in the relay so that only a part of the total current flows through the bimetallic element.
In order to prevent magnetic tripping of this element the moving plate located in front of the element is made of non-magnetic metal (brass). Operation is identical to that of the a.c. thermal magnetic relays.



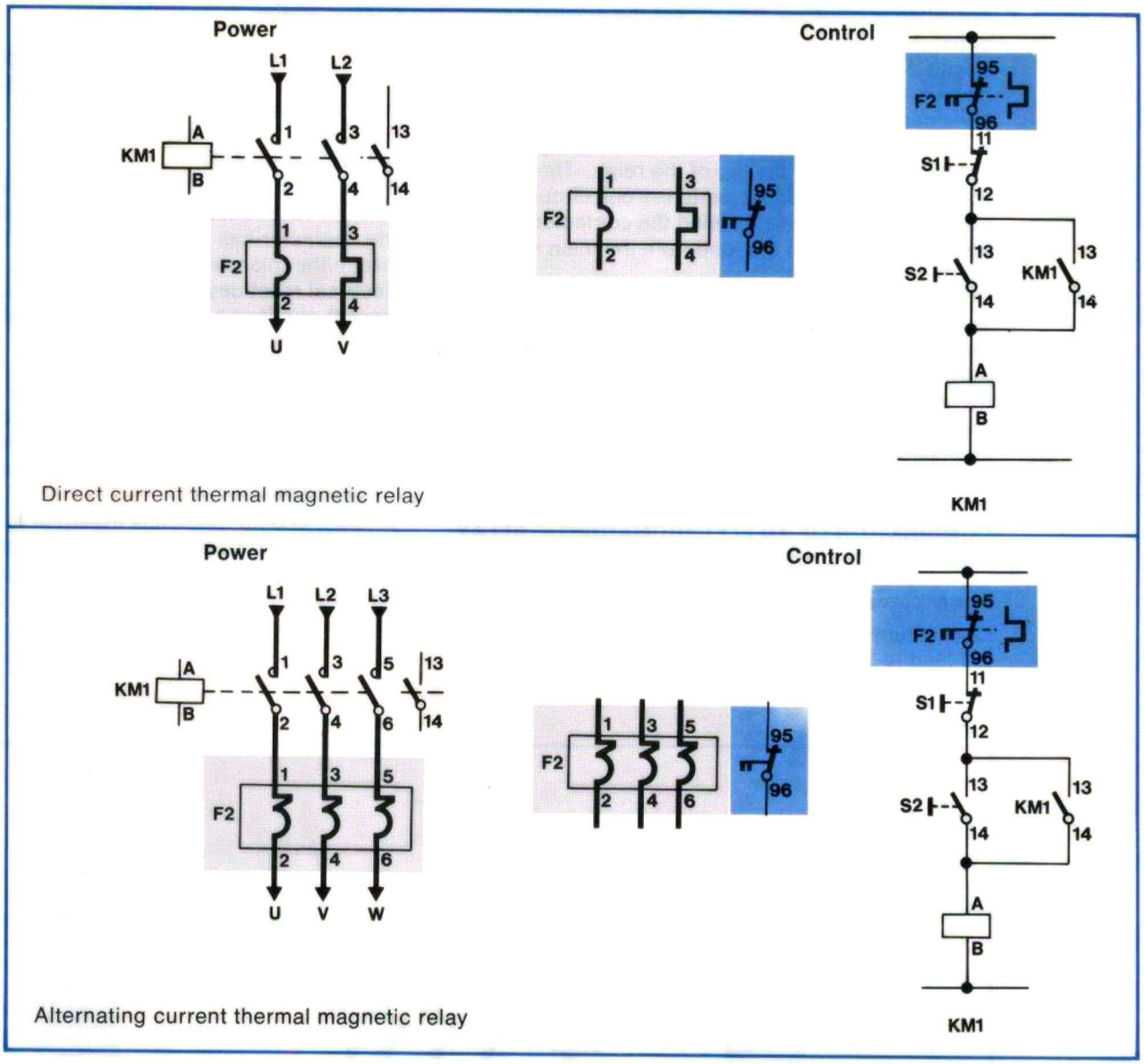
COMBINATION OF A THERMAL MAGNETIC RELAY AND A CONTACTOR

Power circuit

Thermal magnetic relays must be used with contactors having a breaking capacity higher than the prospective short-circuit current of the installation. Otherwise protection against short circuits should be provided by fuses with a thermal relay for protection against overloads.

Control circuit

As in the case of thermal relays the trip contact of the relay should be connected in series with the coil circuit of the contactor.



ELECTROMAGNETIC OVERCURRENT RELAYS

Electromagnetic overcurrent relays are designed to provide protection against high overloads in installations subjected to frequent current peaks (starting of slipring motors used with hoisting equipment for example). They may be used to protect motors against too frequent starting, sudden variations in load torque or where conventional thermal relays cannot be used.
These relays can also be used to provide protection against short circuits provided that they are associated with a contactor with sufficient breaking capacity.

All of the component parts in the equipment should also be able to withstand stresses due to short circuits.

Principle of operation

Each relay contains:
- a magnetic circuit consisting of a fixed part, a moving part and a coil,
- a certain number of "C/O" contacts,
- an air gap setting device,
- connecting terminals.

The coil, whose section is a function of the current flow, is connected in one of the phases of the load. With the current flowing through it the coil produces a magnetic field which in normal

operation is insufficient to attract the moving armature. When a high overcurrent or a short circuit occurs the magnetic field as well as the ampere-turns produced by the coil increase considerably; the moving armature is attracted thus actuating a cam which reverses the auxiliary contacts located at the top of the relay. The N/C contact, which is connected in the coil circuit of the main contactor, opens causing the contactor to open and cutting off the load from the main supply.

Setting device

The relay is set by means of a drum containing a helical strip which adjusts the opening angle of the moving armature thus changing the air gap and therefore the value of ampere-turns required to close the magnetic circuit. Since the drum is graduated in amperes it is only necessary to set the pointer to the load current.

COMBINATION OF AN ELECTROMAGNETIC RELAY AND A CONTACTOR

Power circuit

Connection of a relay in each of the lines supplying the load to be protected.

Control circuit

The trip contact of each relay can be either a latching contact or a non-latching contact and should be connected in the coil circuit of the contactor.

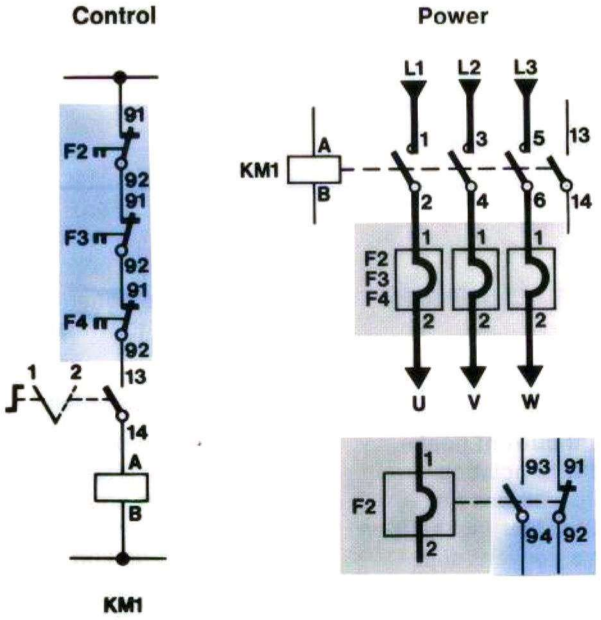
— Latching contact.

When the relay is tripped the contacts are held mechanically which inhibits their resetting after the line contactor has opened. This type of relay is reset either manually or by means of a remote electrical reset device. This device is used to prevent chattering of the contactor and its closing on to a short circuit.

— Non-latching contact.

After the relay has tripped and the line contactor has opened the current which caused the tripping no longer flows in the main circuit. The relay resumes its initial position and the contactor remains de-energized.

Caution: in both cases it is essential to correct the fault before resetting the relay (with latching contact) or before pressing the start button again (non-latching contact).



2 wire control
(latching contact)

Push-button control (3 wire)
(non-latching contact)

short circuit protection

FUSES

Fuses provide protection in each phase and offer high breaking capacity in a small volume. There are various types complying with the standards of individual countries and are classified in two categories:

Distribution type cartridges

These protect against short circuits as well as overloads in circuits without high current peaks (e.g. heating). In general the cartridge rating should have a value just above that of the full load current of the protected circuit and the cable cross section should be taken into account.

Motor type cartridges

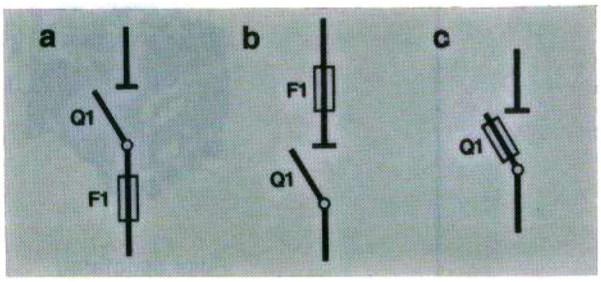
These cartridges protect only against short circuits on equipment experiencing high current peaks such as induction motors or electromagnets. It is essential that protection against overloads be provided by another device (for example a thermal overload relay) because a fuse cartridge continuously carrying a current 2 to 3 times higher than its rating heats up excessively but does not blow.
In general the cartridge rating should be just above the full load current of the protected circuit.

HIGH BREAKING CAPACITY CONTACTORS WITH SPECIAL RELAYS

These are high breaking capacity (100 to 200 In) contactors associated with magnetic relays and sometimes with an increased impedance so as to reduce the value of the prospective short circuit current.

TELEMECANIQUE FUSED ISOLATORS

Various types of fuse and isolator combinations are recommended depending upon the code of practice in each country:
• Isolator on the supply side, fuse on the load side.
Protects personnel when replacing fuse.
Isolator not protected in case of short circuit (fig. a).
• Fuse on the supply side, isolator on the load side.
Personnel not protected when changing fuse.
Isolator protected in case of short circuit (fig. b).
• Fuse incorporated in the isolator.
Personnel are protected when changing fuse (fig. c).
Isolator protected in case of short circuit.



Telemecanique isolators are block devices which can incorporate, for most ratings, either cylindrical or blade fuses or links. They are actuated be means of a handle placed at the right or left as desired providing two positions corresponding to the open and closed states of the circuit.
In the open position the contacts are separated by an isolating distance conforming to the standards of various countries.
These isolators are available in three pole, four pole and in some cases five pole models. The incorporated auxiliary contacts which open before the main poles must be connected in the control circuit of a contactor so that on load breaking is performed by the contactor.

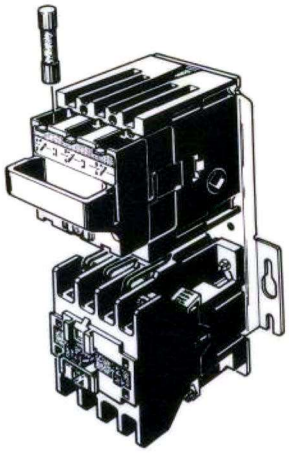
The functions provided depend upon the design of the equipment:

- Isolators with links.

Poles are equipped with links permitting these devices to be used for isolation.

- Isolators with fuses.

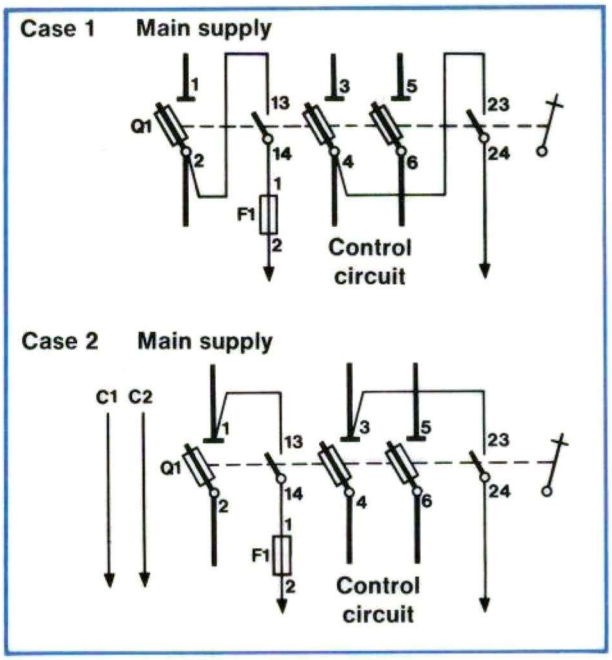
The links are replaced by fuses; in addition to the possibilities offered above, the load, control equipment and cables are protected against short circuits.



Fuse asociated with a contactor

Two cases can arise:

- the contactor control circuit is connected on the load side of the isolator. The blowing of the two fuses causes immediate opening of the contactor: protection is complete (case 1).



- the contactor control circuit is connected to the supply side of the isolator or to a separate source. In this case the contactor remains closed and the voltage which remains across one of the motor windings presents a danger to personnel and equipment (case 2).

We manufacture isolators with a striker fuse mechanism.

When one or more fuses blow the strikers operate the contact which signals the fault or automatically opens the contactor which supplies the load.

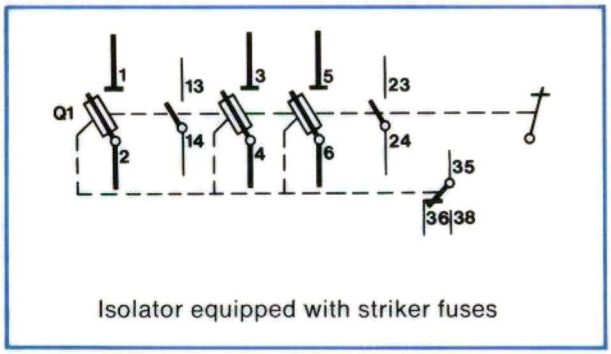
FEATURES OF TELEMECANIQUE ISOLATORS

Equipment can be tested off load

Off load tests can be carried out by simply tilting the fuse carrier or after removing the fuse cartridges or links, the supply being cut off without having to disconnect the cables supplying the load. When the isolator is reclosed the control circuit is again connected permitting off load tests.

Isolators equipped with striker fuses

When protection is provided by fuses and differential thermal relays the blowing of two fuses causes the motor to stop immediately but since no current flows through the relay it is not tripped.



Isolator equipped with striker fuses

Interlocks

When the unit is mounted in an enclosure or cabinet an additional device is available to prevent opening of the door if the isolator is in the closed positon.

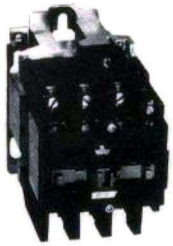
ASSOCIATION OF AN ISOLATOR, CONTACTOR AND THERMAL OVERLOAD RELAY (schematic on page 36)

Isolator

Isolation of power (off-load) and control circuits.
Protection of motor, equipment and the supply lines against short circuits.
Possibility of no load test of contactor equipment.

+ Contactor

Manual or remote automatic control. Protection against loss of voltage or large voltage drops. High rate of operation and long life.



+ Thermal overload relay

Protection against small and sustained overload, phase failure and phase imbalance.

= Flexibility of control and complete protection of the whole installation.

ON LOAD DEVICES

When the power of an installation is high, with a risk of high short circuit currents, a protective device equipped with fuses is recommended. This device, having a high making and breaking capacity, should be capable of being switched on-load and of providing complete safety for personnel.

Switching function

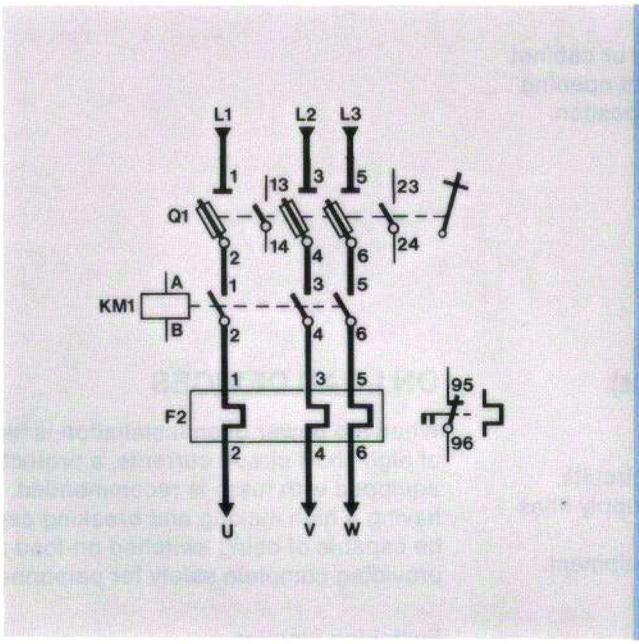
Fitted with links or fuses Telemecanique on load devices, with a breaking capacity of 8 In, are in compliance with the international publication IEC 408 including the most severe duty category (AC 23). Fitted with fuses, breaking capacity is aided by that of the fuses which is at least 50 KA for a Vn $\leqslant$ 500 V (most fuse manufacturers guarantee 100 KA). The making capacity of an on load device equipped with fuses is identical to its breaking capacity.
These results are due to:
- switching speed independent of the action of the operator;
- high speed of operation of the device;
- arc chambers with blow outs.

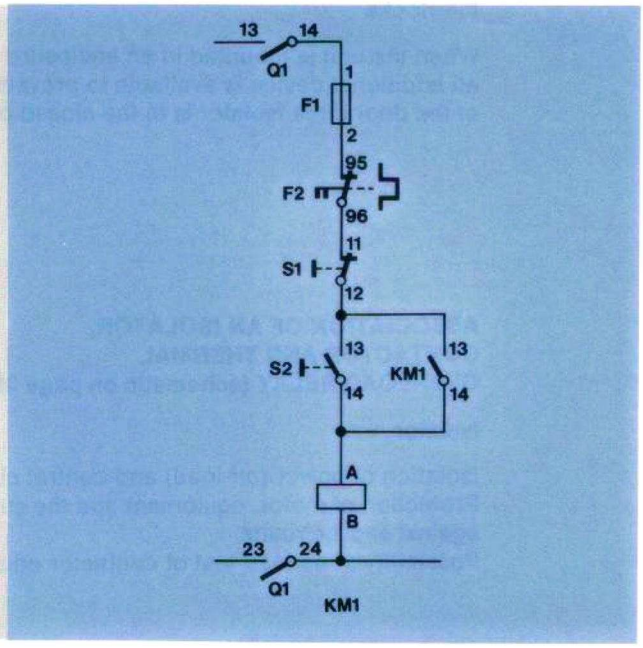
Isolating function

Telemecanique isolators guarantee the safety of personnel working on the load side because:
- they have high insulation voltage;
- no live parts accessible;
- isolating distances conforming to the standards of various countries;
- disconnection visible for all vital parts;
- additional safety position by tilting the fuse carrier. In this position the main circuit cannot be re-closed by the handle even if it has not been locked;
- access to fuses is impossible when the isolator is closed so preventing their removal when live;
- locking of the handle, by up to three padlocks, in the open position only.

Protection function

Fitted with fuses these devices protect the whole installation against short circuits.





protection of high inertia motors

ASSOCIATION OF AN ON LOAD DEVICE, CONTACTOR AND THERMAL OVERLOAD RELAY

On load device

No load breaking or on load breaking even on short circuit.
Protection of the lines and loads.
Visible contact separation.
Lockable handle.

+ Contactor

Manual or remote automatic control. Protection against supply failure or voltage drops. High rate of operation and long life.

+ Thermal overload relay

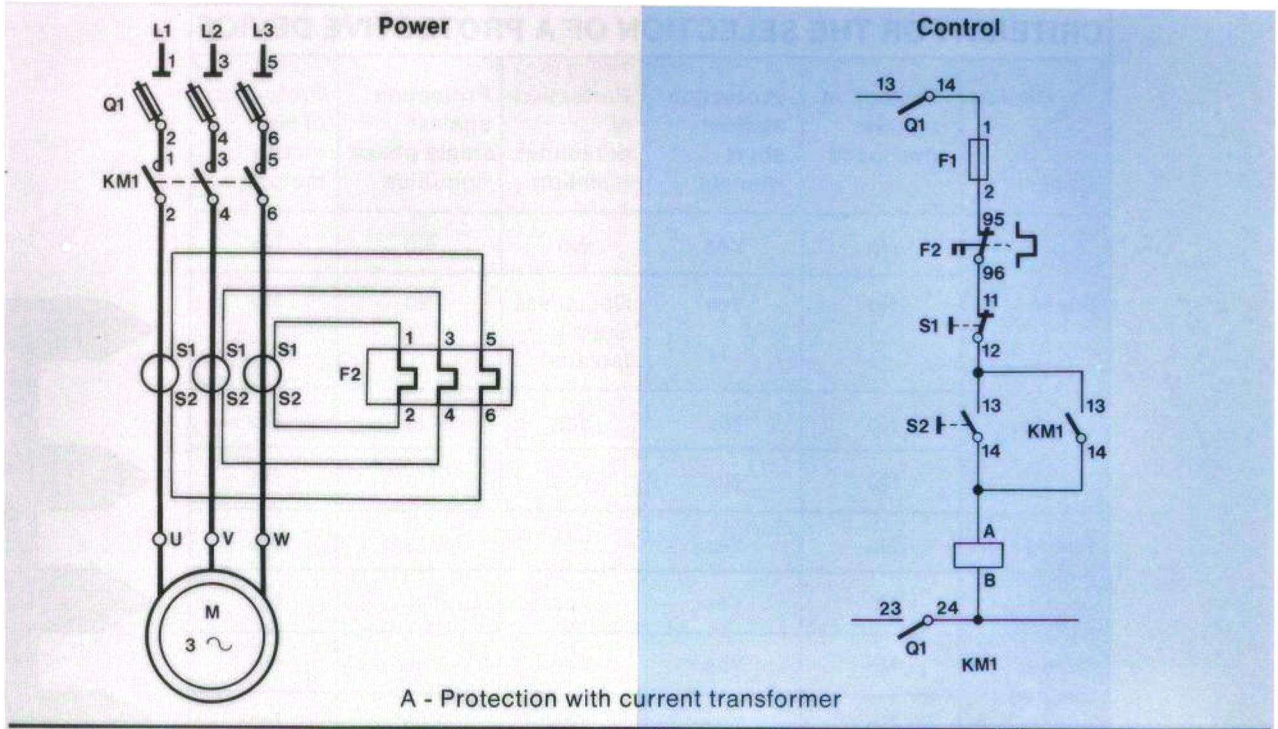
Protection against small and sustained overloads, phase failure and phase imbalance.

= Flexibility of control and complete protection of personnel and the complete installation.

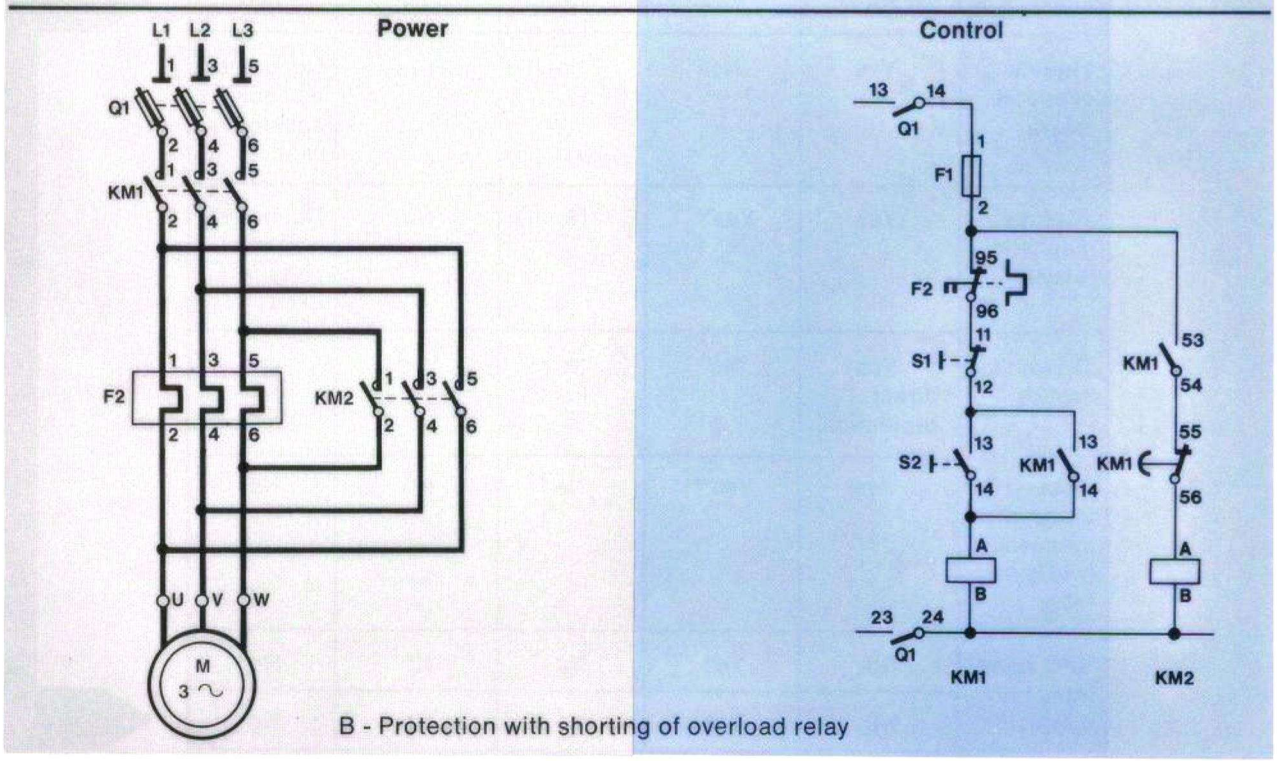
High inertia motors are sometimes difficult to protect since the thermal overload relay is tripped before the end of the starting cycle. The use of an oversize relay will sometimes allow the starting current peak to be passed but after that, when the motor takes its normal current, the protection would be inadequate. That solution should therefore be rejected in favour of those mentioned below.

- Use a thermistor protective device (refer to page 29).
- Use a thermal relay supplied by the secondaries of three current transformers (schematic A).

During starting and before the current peak is over, the transformers are saturated so the current in the bimetal strip inceases less than in the protected circuit.
For small overloads the protection is identical to that obtained by thermal overload relays supplied directly whereas for higher currents the tripping time is longer.



A - Protection with current transformer



B - Protection with shorting of overload relay

• By means of a contactor, short out the protection relay during the entire starting period (schematic B). At the end of the starting period, a timed auxiliary contact opens the shorting contactor.
Whichever solution is chosen HRC fuses will protect the motor against short circuit during starting and during normal operation.
Note: Since the starting curves of high inertia motors are not identical each case needs consideration; please consult us for advice.

CRITERIA FOR THE SELECTION OF A PROTECTIVE DEVICE

Choice / Device	Protection against overloads	Protection against short circuits	Protection of personnel, isolation	Protection against single phase condition	Protection of high inertia motors
Fuses	No	Yes	No	No	No
	No	Yes	No, unless Supply Isolated	No	No
Isolators	No	No	Yes	No	No
	No	No	Yes	No	No
Fused isolators	No	Yes	Yes	Yes*	No
	No	Yes	Yes	Yes*	No
Onload devices	No	Yes	Yes	Yes*	No
	No	Yes	Yes	Yes*	No
Thermal overload relays	Yes	No	No	Yes	No, unless a special scheme is used
Thermal magnetic relays	Yes	Yes**	No	No	No, unless a special relay is used
Thermistor probes	Yes direct protection	No	No	Yes	Yes
Instan-taneous magnetic overload relay	Yes	Yes**	No	No	No
HRC relay fitted on a contactor	No	Yes	No	No	No
	No	Yes	No	No	No

Apparatus being manually operated

* If single phase condition is due to the blowing of a fuse and the unit is equipped with a device inhibiting single phase operation.

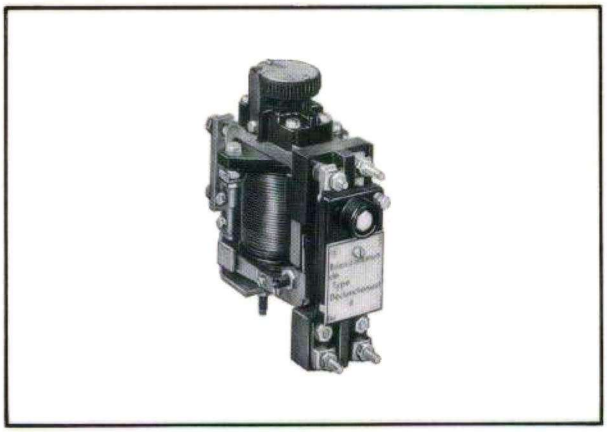
** If in association with a contactor having sufficient making and breaking capacity.

Frequently used with automatic contactor gear, measuring relays control and monitor the value of the voltage supplied by a generator or the current taken by a load.
When the current or voltage reaches the predetermined value these relays operate and by means of contactors stop the generator, disconnect the load from the main supply or shed load via clutches, for example.

measuring relays

CURRENT MEASUREMENT

Measurement of current is simple and is used particularly to monitor the load of machines as well as that of installations. Depending upon the conditions of operation and the type of machines involved the relays are actuated by overcurrent or undercurrent.

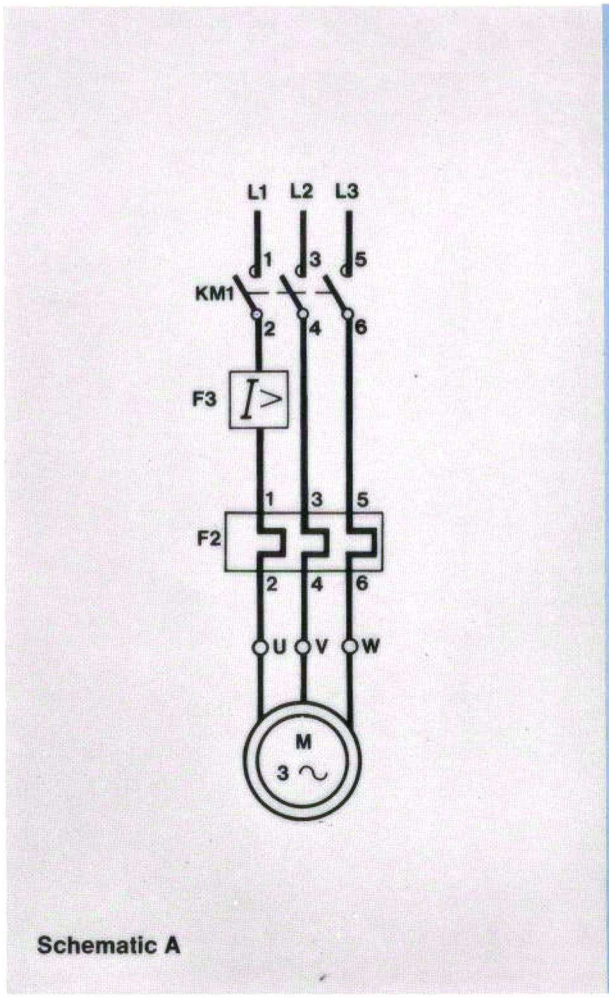


OVERCURRENT OPERATION

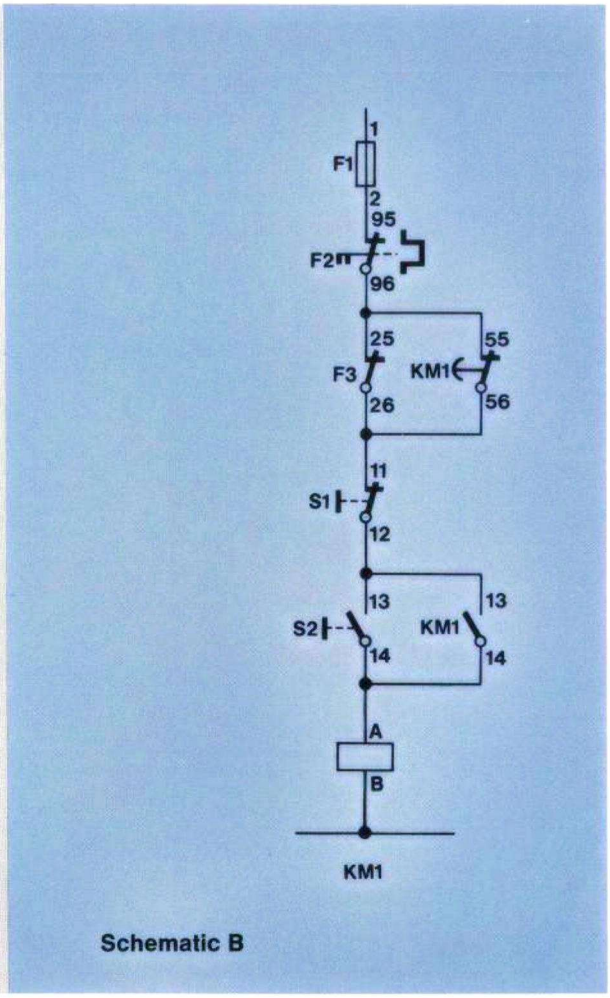
Excessive overcurrent actuates the relay.

Stall relay (schematics A-B)

A relay in series with one of the motor windings measures the current so that when the current increase due to an increased load, the relay cuts off the motor completely (fig. below) or re-inserts a part of the starting resistance so reducing the speed and limiting the torque.
When the normal current flows again operation of the start button will restart the motor or, in the case of automatic equipment, the closing of the contact on relay F3 will short circuit the resistance previously inserted and the original state will be restored.



Schematic A



Schematic B

Note: In order to balance the action of the relay during the starting period contact 25-26 is shorted by a timed contact until the current falls (55-56 on KM1).

UNDERCURRENT OPERATION

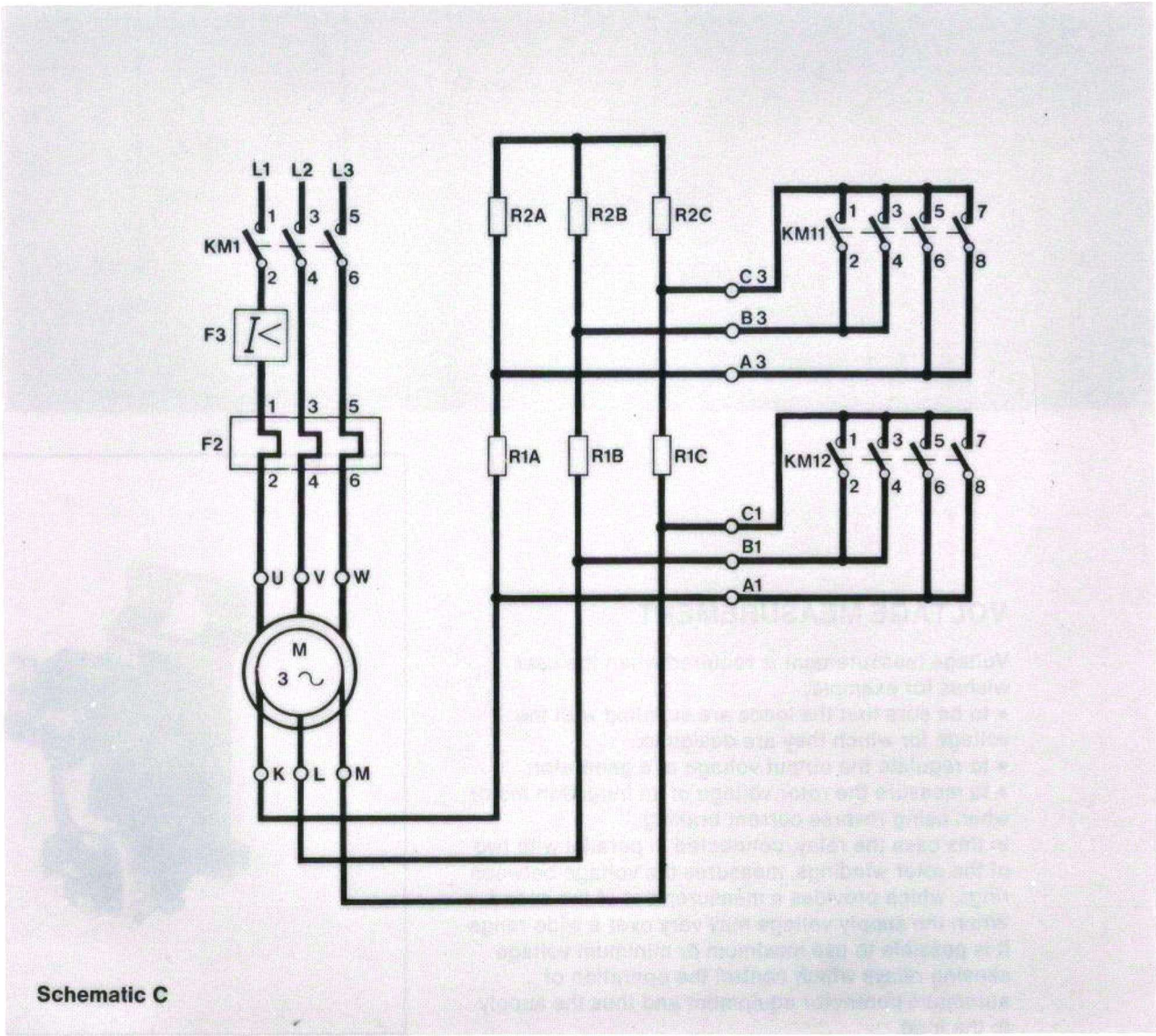
Contrary to the previous case it is the reduction of current to the load which causes the relay to operate.

Relay for current limit starting (schematics C-D)

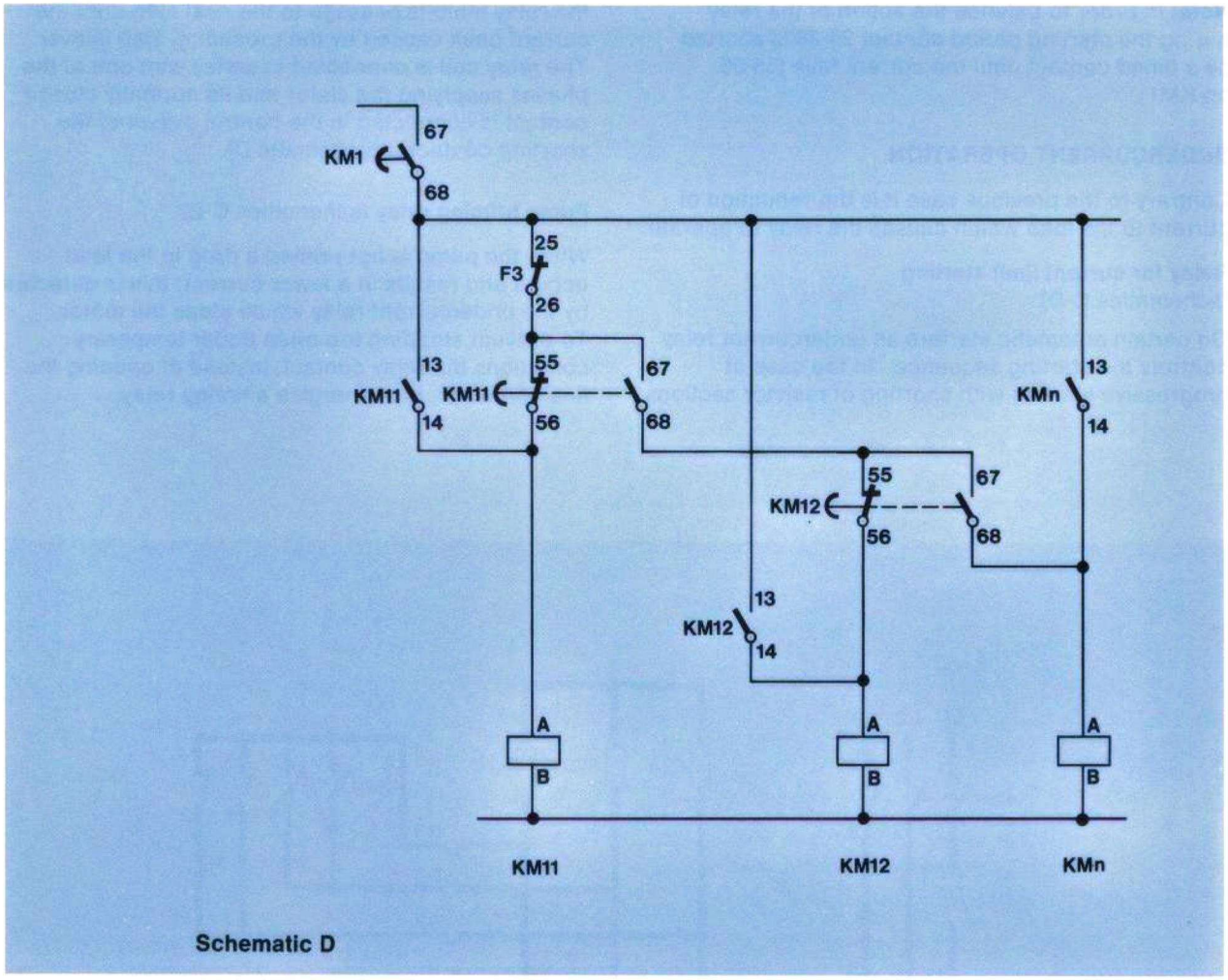
On certain automatic starters an undercurrent relay controls the starting sequence. In the case of progressive starting with shorting of resistor sections, the relay inhibits passage to the next step until the current peak caused by the preceding step is over. The relay coil is connected in series with one of the phases supplying the stator and its normally closed contact is connected in the control circuit of the shorting contactor (schematic D).

Pump priming relay (schematics C-E)

When the pump is not primed a drop in the load occurs and results in a lower current; this is detected by the undercurrent relay which stops the motor. To prevent stopping too often under temporary conditions the relay contact, instead of opening the line contactor, may energize a timing relay.



Schematic C



Schematic D

VOLTAGE MEASUREMENT

Voltage measurement is required when the user wishes for example:

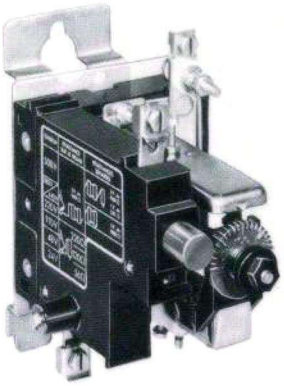
- to be sure that the loads are supplied with the voltage for which they are designed.
- to regulate the output voltage of a generator.
- to measure the rotor voltage of an induction motor when using reverse current braking.

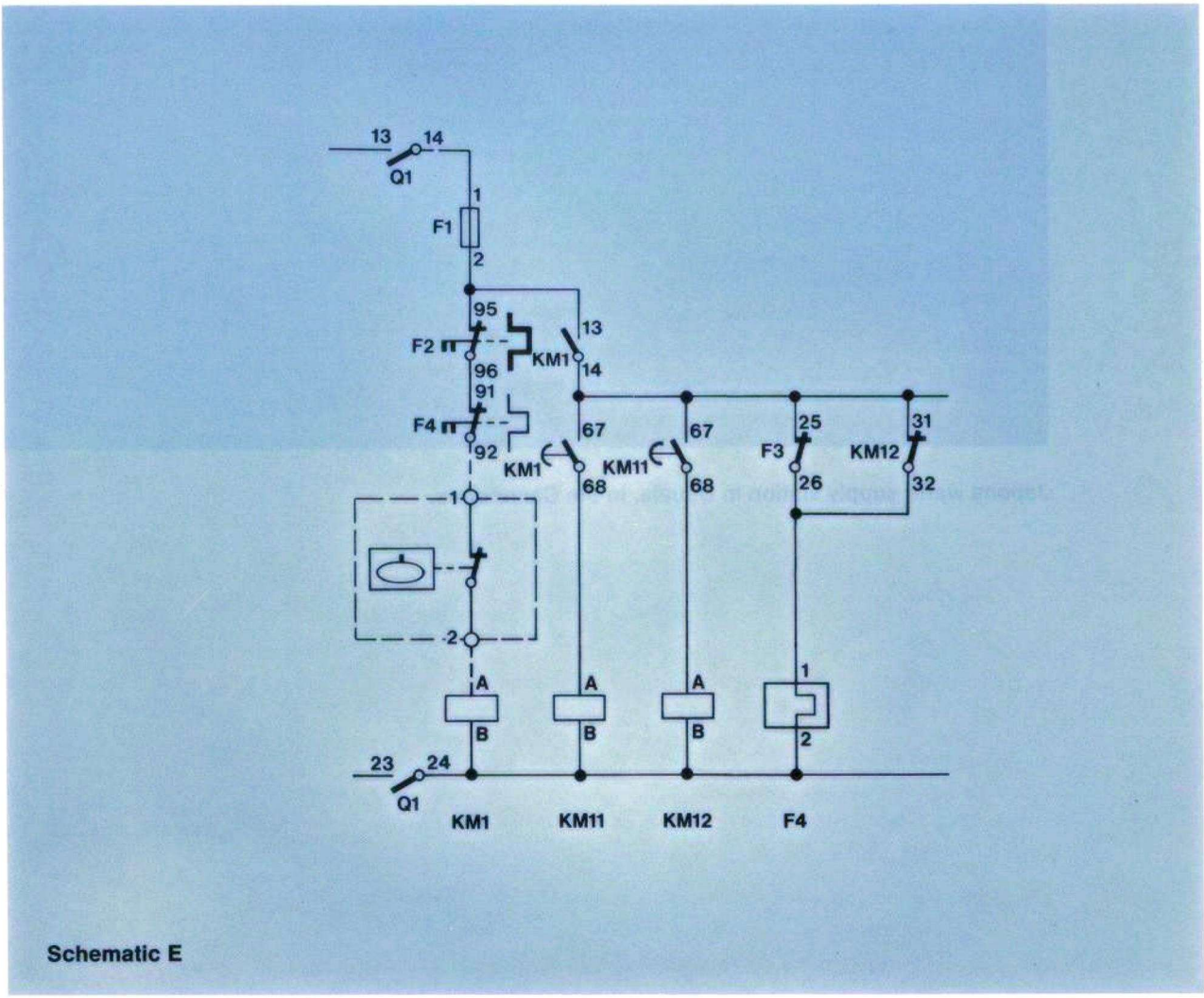
In this case the relay, connected in parallel with two of the rotor windings, measures the voltage between rings, which provides a measurement of the speed.
When the supply voltage may vary over a wide range it is possible to use maximum or minimum voltage sensing relays which control the operation of automatic contactor equipment and thus the supply to the load.

TIME MEASUREMENT

In cases calling for:
- the delay in operation of a current relay,
- the timing of the energization of a component,

the thermal time delay relay is recommended if exceeding the time limit should be followed by a shutdown.
The thermal element, connected to the main supply by the closing of a contact or by action of a current relay, measures the elapsed time from that moment. This device is often used to protect starting resistors against sustained or too frequent starting or to delay the action of an instantaneous measuring relay (schematic E).
The relay is fitted with a manual reset device so that the operator must notice the fault before resetting.





Schematic E

Japona water supply station in Douala, in the Cameroons.

Pilot Devices are used to switch low currents such as those flowing in the coils of contactors (* page 46).
By means of the contactor the motor or other load can be controlled either by an operator manually, or by a physical value in which case the control is automatic.
In the above cases the signal is transmitted to the contactor coil through a contact or through an equivalent electronic switching device.
We shall describe:

- **The principle of the Pilot Device.**
- **The Pilot Device for manual control.**
- **The Pilot Device for automatic control.**

PRINCIPLE OF THE PILOT DEVICES

The manufacturer must keep three essential points in mind when designing a Pilot Device:
- when a command is given by operating personnel the operator is not considered to be an electrician and his role is simply to perform his duties without concern for the electrical function.
- when the control is automatic the user is to be relieved of all problems concerning the cycle of operation.
- in both cases personnel and equipment must be protected.

Regardless of the type of control, the auxiliary consists of three main parts:

OPERATING HEAD

There are numerous operating heads and they are chosen according to the conditions of use and the type of command to be given:
- manual control using a push button, rotary switch, pedal, handle, control wheel, etc.;
- automatic control using a limit switch, pressure switch, float switch, etc. In this type of control the choice of auxiliary also depends upon the type of material to be controlled, i.e. solid, liquid, gas, the speed and mass of the moving part and the frequency of switching.

CONTACTS

Pilot devices are equipped with a certain number of contact combinations N/C, N/O, N/O + N/O, N/C + N/O.
On certain models, contact opening and closing time is a function of the actuating speed of the operating head; on others, with an over centre mechanism, opening and closing positions are precise.

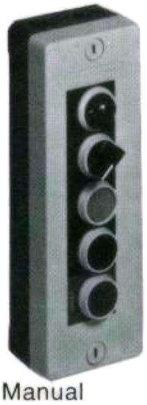
ENCLOSURE

Although many control units are mounted on panels or consoles many are also mounted in enclosures selected as a function of operating and environmental conditions. Enclosures protect:
- personnel against accidental contact with live parts;
- the control unit against dust, liquids, shocks, etc.

Since all metal parts used in the manufacture of pilot devices are cadmium plated and passivated they can be used in all ordinary climates and environments but special treatments are applied for use in hot and humid conditions or in corrosive atmospheres.
Control auxiliaries with explosion proof enclosures are recommended for use in such atmospheres.

(*) In this particular case series limit switches and certain control unit contacts connect in the power circuit are classified as "pilot devices".

PILOT DEVICES



Manual

Automatic

MANUAL CONTROL

Manual control should:
- provide for the safety of the operator as well as the machine;
- be simple, reliable and rugged;
- relieve the operator, through correct positioning of the controls, of unnecessary or tiring movements;
- inhibit the starting of the machine if certain precautions have not been taken (doors closed, lubrication, etc.);
- if necessary, permit control from several stations;
- prevent any unwanted starting after a supply failure.

The operating conditions and location and the characteristics of the circuits to be controlled are the main criteria which determine the choice of manual pilot devices.

CONTROL AND SIGNALLING CIRCUITS

Push button stations

Push button stations are equipped with contacts which:
- close or open as long as the operator is depressed and then return to their initial position (momentary contacts);
- remain in the position in which they are placed by action of the operating head (stay put or latching contacts). In this case a second action is required to cancel the preceding one.

The command is given by:

Push buttons

- flush: prevent any unintentional operation.
- projecting: for operation with gloved hands.
- booted: for use in dusty areas (cement factory, foundry, construction site equipment) and special environments (dairy).
- mushroom-headed: for fast action, emergency stop.
- wobblestick: for movement in any direction.

Rotary Knobs or Keys

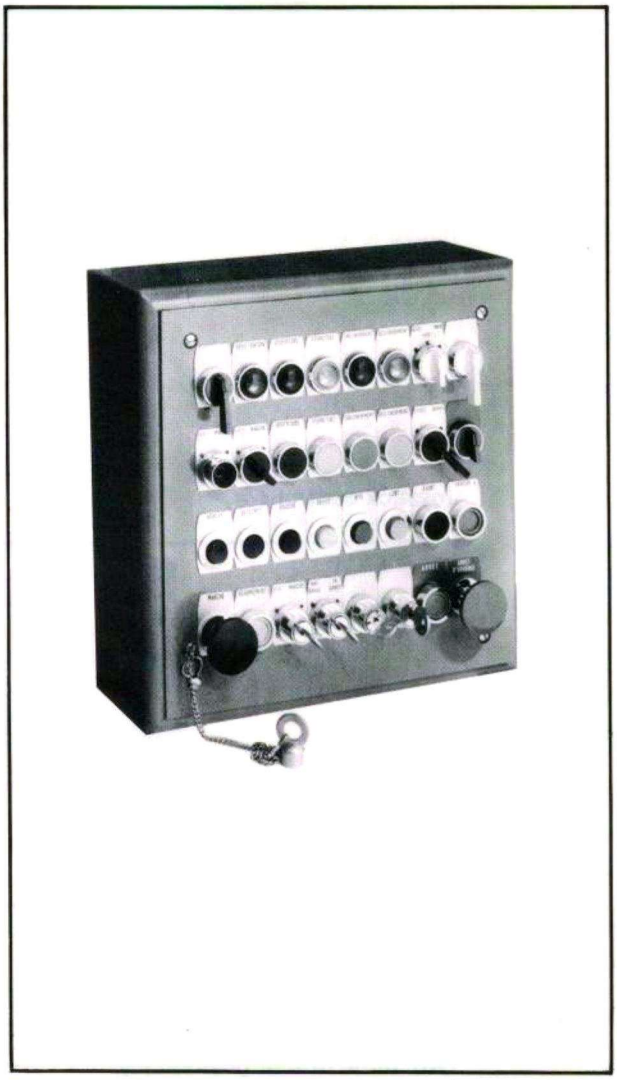
With two or three fixed positions and/or spring return action (for selection of circuits i.e. manual, automatic and stop on equipment such as a compressor or pump).

When controlled by a key (removable or trapped in certain positions) only the authorised person can operate the switch.

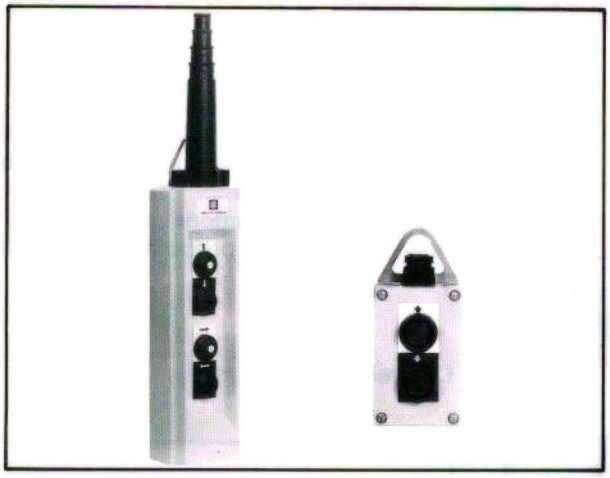
Indicator lights

Indicator lights, with bulbs supplied directly or, through resistance or step down transformer, complete the range.
Illuminated push buttons are combined units providing compact pushbutton control and indication.

Control stations

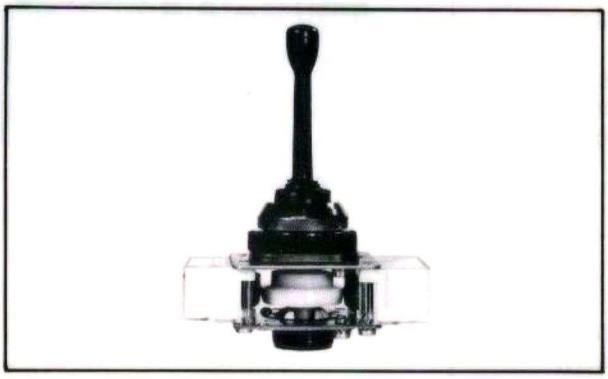


Pendant control stations



Pendant control stations are designed to control hoisting equipment (pulley blocks and cranes).
Power contact blocks ensure direct control of motors (see next page).
Alloy or fibre glass reinforced polyester enclosures house a variable number of contact blocks.

Joystick controllers



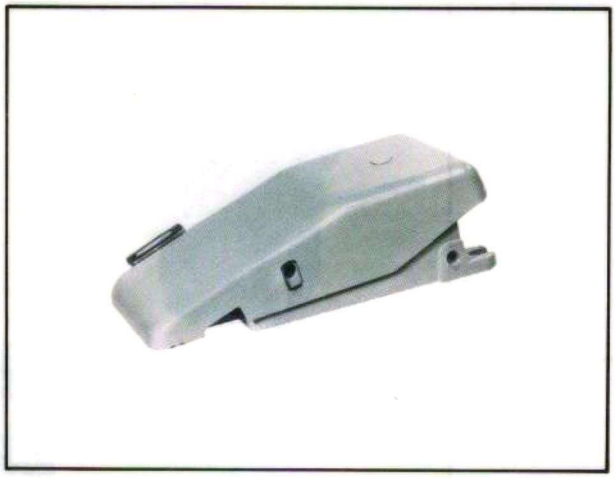
Two, three or four position joystick controllers with stay-put or spring return action, for use with contactors to control numerous plants (machine tools, light lifting and handling equipment, etc.).
Available in two models: normal and heavy duty.
Operated by means of a lever or pistol grip.

Controllers

Controllers are used for semi automatic control of lifting equipment (winches, gantry cranes, travelling cranes, etc.) and handling equipment.
Their multiple contacts control through contactors, the starting, acceleration or braking of motors.
Single drum controllers control a single movement only, whereas dual controllers (with universal lever) permit separate or simultaneous control of two movements with a single control lever.
Available in two versions: for normal duty or heavy duty. The latter being particularly rugged is recommended for hoisting applications and in steelworks.
The controllers are operated by means of a vertical lever, a handle, pistol grip or wheel and are often incorporated in control stations (control desks, portable stations, seated units).

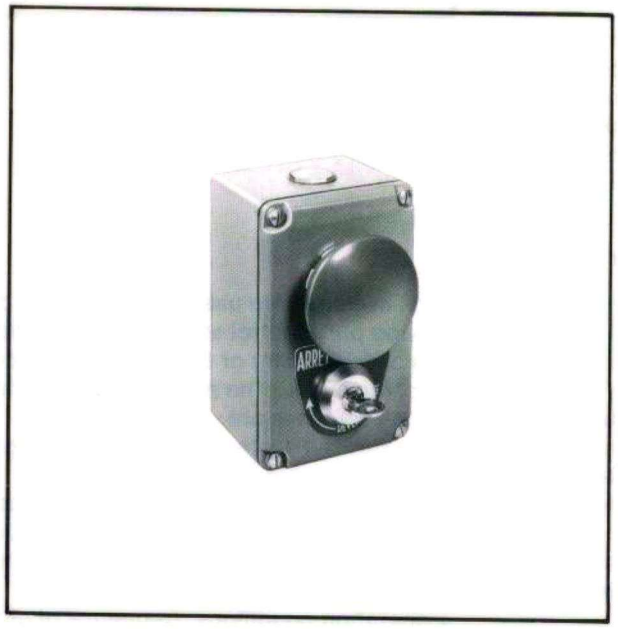
UNITS FOR SPECIAL APPLICATIONS

Foot switches



Of the spring return or latching type, these switches are used to control various types of machine (grinders, drilling machines,presses, welders). They are used frequently when the operator has both hands occupied and are used to switch contactors.

Emergency stop and lock



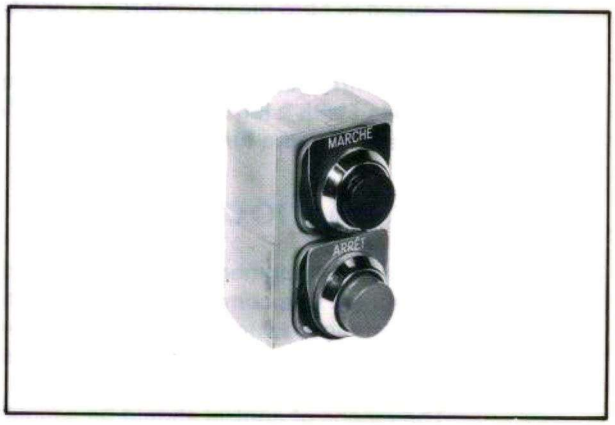
When the mushroom headed push button is depressed it is locked in the depressed position stopping the installation and preventing restarting. Only personnel having the key can reset the button.

Fire alarm stations

These units are opened and operated by a key or the glass is broken with a hammer supplied with the station.

DIRECT CONTROL OF LOW POWER MOTORS

Control units



These units provide direct switching of low power loads. They are composed of a triple pole contact block with quick make and break contacts and an operating head actuated by button, knob or lever. These units are compact and easily mounted on panels or in control stations and desks.

Pendant control station

These are used especially for the direct control of low power lifting equipment (pulley blocks, overhead cranes, small travelling cranes, etc.). The snap action contact blocks, mechanically interlocked, are housed in fibre glass reinforced polyester enclosures resistant to shock and chemicals.

The control auxiliaries described above are supplied with a legend plate with wording or a sign representing the function.

AUTOMATIC CONTROL

Contactor equipment can be controlled by the movement of a component (limit switch) a variation in level (float switch), temperature (thermostat), pressure (pressure switch), vacuum (vacuum switch), wind speed (anemometer), etc.
The means of control should be simple and reliable to eliminate problems for the user but sufficiently strong to withstand repeated operation.
With automatic control applications are unlimited (transfer machines, cranes, rolling mills, grain silos, etc.). These are complex examples but the diversity of control auxiliaries permits often inexpensive design of equipment offering complete safety for the personnel as well as full machine control.

MACHINE SLIDE CONTROL

Limit switches

Limit switches are used to monitor the position of a moving part-control starting, deceleration or stopping at a specific point or to control the automatic machine cycle. The main factors affecting the choice of limit switches are:
- the desired protection again touching, physical shocks, splashing of liquids, etc.;
- the type of environment: humidity, dust or corrosion as well as ambient temperature;
- space available for positioning and fixing the switch;
- operating conditions: frequency of operation, type and speed of the slide to be monitored, required accuracy and reliability; possible overtravel in either direction, force required to actuate the contact;
- the number and type of contacts; slow or quick make and break: possibility of adjustment;
- the nature and value of the control voltage and load current.

Static proximity detectors

Mechanically actuated control auxiliaries allow a great number of problems to be solved, but for selected applications they may be replaced by static versions. These detectors fulfil functions similar to those of limit switches but their design is completely different; being entirely static they have no operating head (lever, roller, etc.) and the contact is replaced by a thyristor.
These devices:
— have no moving parts;
— have a life independent of the number and frequency of switching operations;
— are immune to humid, viscous, dusty, abrasive or corrosive environments;
— have a very short response time therefore a high operating speed;
— provide low level switching with high reliability.
Detection does not require contact with the object therefore no physical stresses are exerted on it.
According to the model, the passage of the object to be detected causes:
— the conduction of a thyristor output stage (N/O);
— or the cut off of a thyristor output stage (N/C);
— or the conduction of one of the stages and the cut off of the other (C/O).
On some models the output state is indicated by a pilot light located on the detector.

Photoelectric detectors

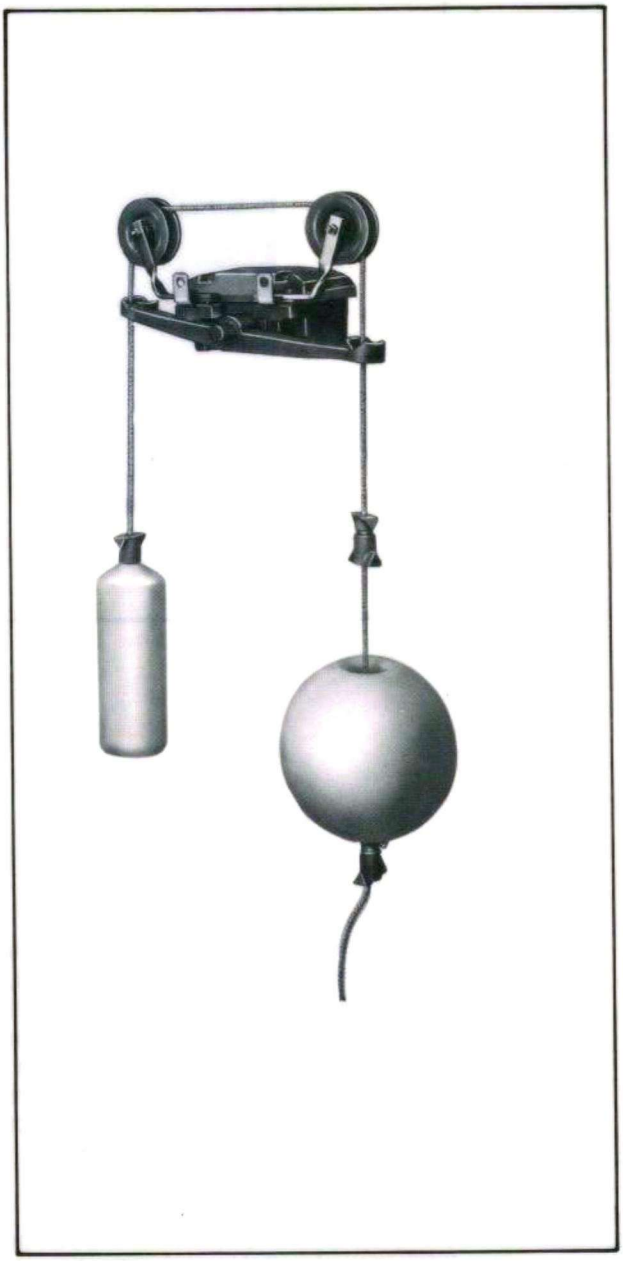
Photoelectric detectors signal the presence or the passage of an object through a light beam.
Two systems are used:
— "Reflex" system
A single enclosure contains the transmitter and receiver and the light beam from the transmitter passes through a multiprism reflector. This system is economical, easy to wire and adjust but the range is short and it does not detect the passing of a reflecting object.
— "Barrage" system
The transmitter and receiver are separate.
When the light beam intensity reaches a preset level a photocell signal is amplified and an output is switched.
The Barrage system has a greater range than the Reflex system and can detect a reflecting object.
On the other hand the cost is higher, the wiring is more complex and the adjustment more delicate (alignment between the transmitter and receiver).

Limit switches for power circuits

In contrast to other pilot devices whose contacts are wired in the control circuit those in this limit switch are used in power circuits.
They protect hoisting and handling equipment etc. when the controlled moving member overshoots the specified path; it operates a lever which causes quick opening of the poles. When the member is re-positioned the switch is reset manually.

LEVEL CONTROL

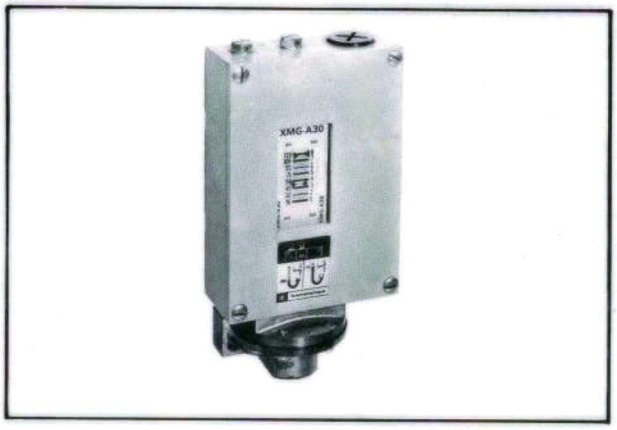
Float switches



Indispensable for pumping equipment driven by electric motors, float switches control the pump in relation to the liquid level in the tank, reservoir, etc. They are designed to control either the high level (feed pump) or the low level (discharge pump) but can also be used to signal the level or for other similar applications.
The choice of switch depends upon the characteristics of the tank, the type and temperature of the liquid and the environment in which operation is required.

PRESSURE CONTROL

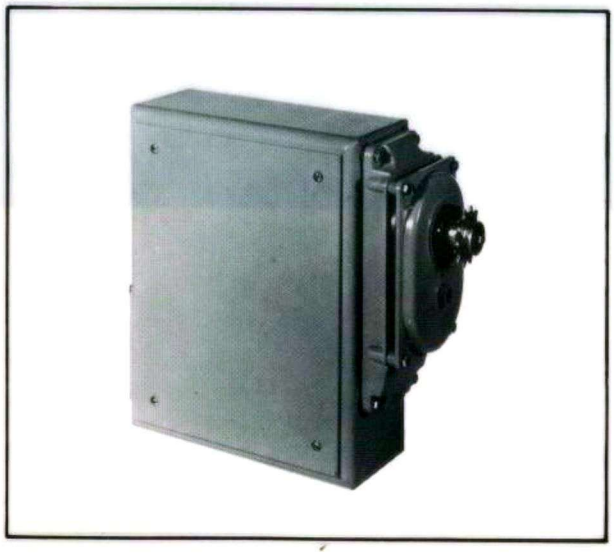
Pressure and Vacuum switches



These units are designed to regulate or monitor a pressure or vacuum in pneumatic or hydraulic systems.
When the pressure or vacuum rises to a preset value the snap action C/O contact operates and when the value of the pressure or vacuum decreases, taking into account the adjustable differential on some models, the contact returns to its initial position. They are frequently used for example:
- to control compressors as a function of air pressure;
- to ensure the flow of a lubricating or cooling fluid.

MULTIPLE POSITION CONTROL

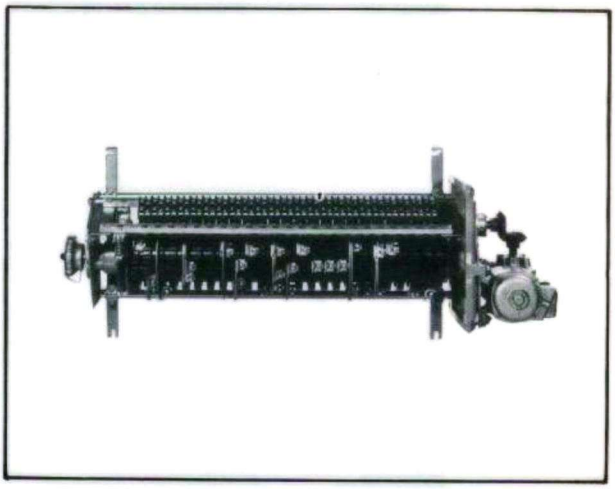
Screw Limit Switches



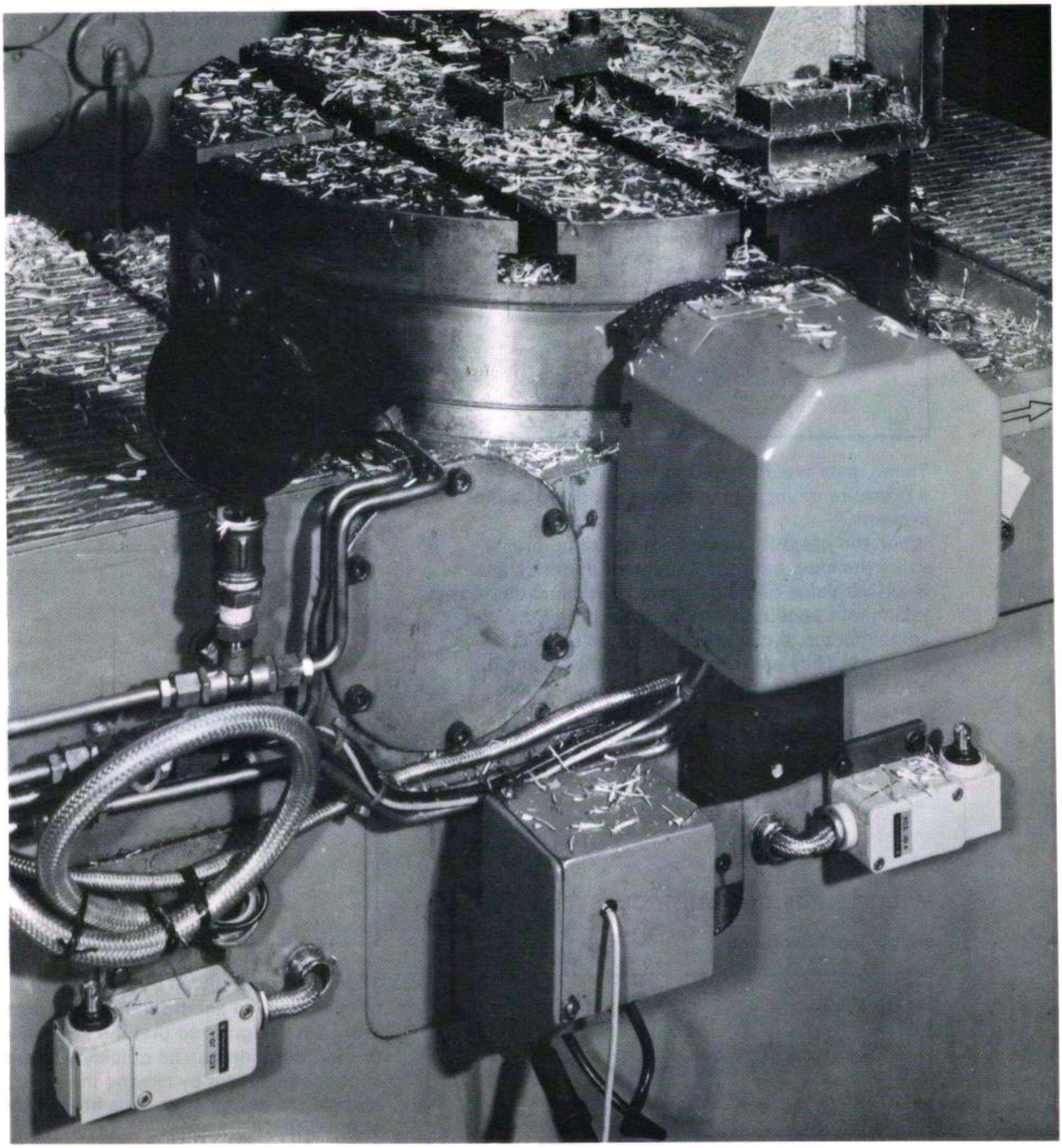
Coupled by means of a chain and reducing gears to a rotating shaft, these are fitted with a number of auxiliary contacts which open or close when the driven component occupies specified positions during its travel i.e. slowing down before a stop, stop at a fixed point, signalling; they are particularly suited for use on lifting or mechanical handling plant. When used in conjunction with a float, which monitors the level in a tank, screw limit control automatically a number of pumps related to flow demand.

SEQUENTIAL TIME CONTROL

Motorised Cam Switches



These units are driven by a motor to control a series of operations in accordance with a preset cycle. They are designed so that the sequence of operations or their duration can be quickly and easily modified; sequences are set by moving the cams, which actuate the contacts, in slots around the periphery of the drum.
Designed for repetitive use these rugged and accurate switches are employed in all branches of industry.



Position switches on machine tools.

The active part of an electrical system consists of control components (contactors, isolators, relays, transformers, etc.) whose roles are explained on a schematic diagram. After the components have been selected the assembly of the equipment requires the use of a range of products to aid the mounting, cabling and protection of the equipment against ambient conditions.

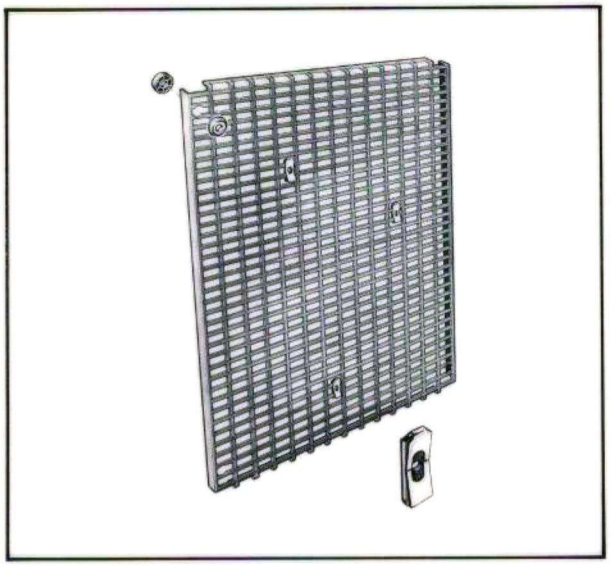
panel building and assembly accessories the "telequick" system

Mounting accessories

Depending upon the equipment dimensions, the method of mounting and the fixing centres of the components the user has a choice of:

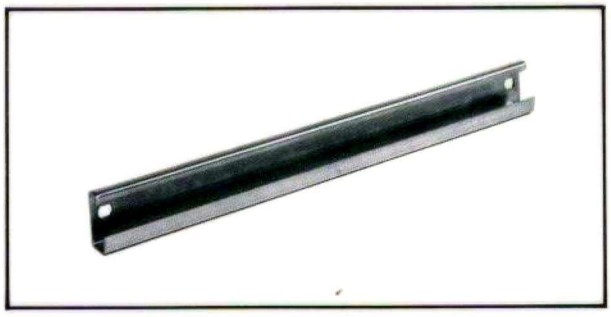
• Universal pre-slotted mounting plates

Adaptable to enclosures and cabinets these plates allow direct mounting, from the front, of all the components regardless of their fixing centres as well as the mounting of cable trunking or clips.
Components are mounted by means of captive clip nuts (∅ 3, 4, 5 and 6 mm) positioned as required from the front.



• DIN mounting rails

Two rails of different section and conforming to standard DIN 46,277 type 1 and 3 are available.
Equipment is mounted:
— either with screws of ∅ 4, 5 and 6 mm on sliding clamps inserted from the front,
— or clipped on using mounting plates or directly if the component is equipped with a base of the appropriate design.



• Pre-drilled uprights

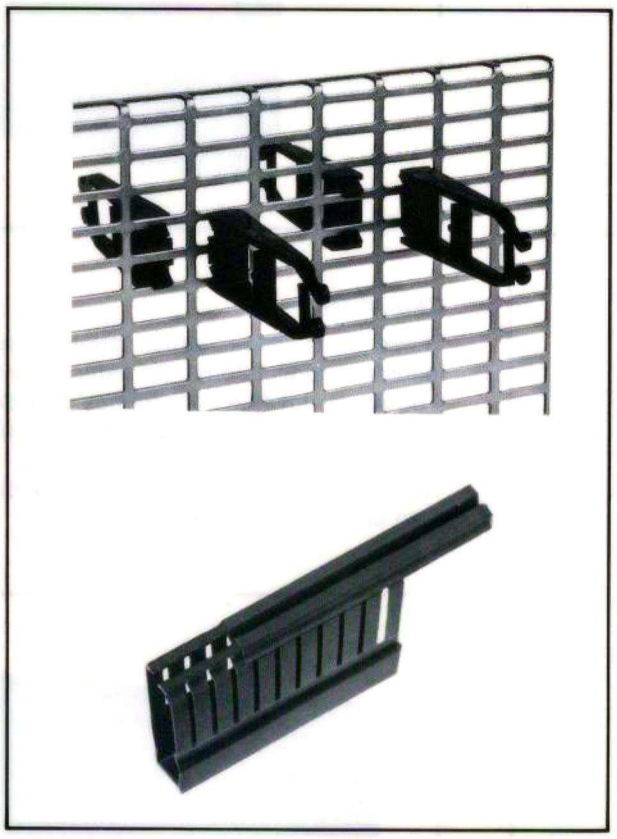
Two types exist of different shapes: c-shape for small panels up to 900 mm height, and Z-shape for larger panels from 900 to 1,920 mm height. Fixing holes are drilled on 20 mm centres.
These holes permit the fitting of captive nuts for the fixing of:
— universal pre-slotted mounting plates,
— DIN mounting rails and bar mounted contactors,
— a combination of plates and rails.

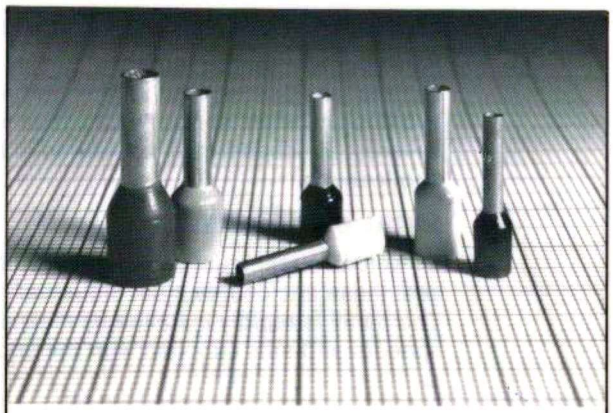
Cabling and terminal accessories

CABLE CLIPS AND SLOTTED CABLE DUCTING

Panel wiring is simplified by the use of cabling accessories whose function is to channel the wires to form horizontal and vertical runs.
All wires are easily installed from the front and trouble shooting and modifications are easily carried out.
For equipment mounted on universal pre-slotted plates horizontal and vertical cabling may be contained in:
— cable clips which may be staggered to accomodate a variable number of wires or,
— slotted cable ducting fixed to the plate.

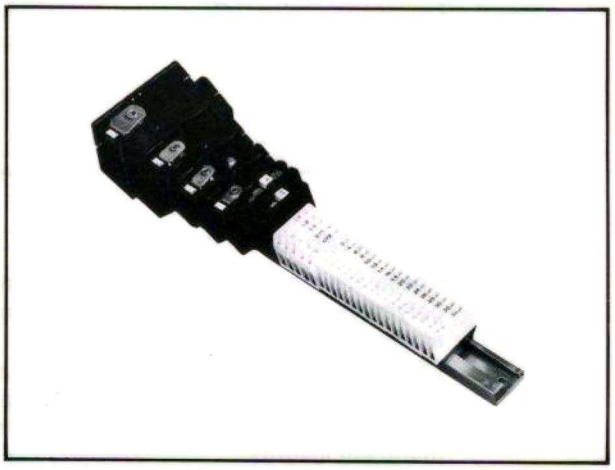
A cover is clipped over the cables clips and ducting to enclose the cables. For equipment on DIN mounting rails horizontal wiring is channelled through the cable clips between the rails used to mount the components; vertical wires are passed through slotted cable ducting, the slots of which may be widened as required.





TERMINAL BLOCKS

Terminal blocks are designed for the connection of conductors having a cross-section up to 300 mm^2. They are clipped onto DIN mounting rails conforming to DIN 46,277 type 1.
The insulated bodies are made of self-extinguishing polyamide and to ease connection the clamps are supplied unscrewed. In addition terminals can be referenced by means of push-in characters.



INSULATED CABLE ENDS AND DUAL ACTION WIRE CUTTING AND STRIPPING TOOL

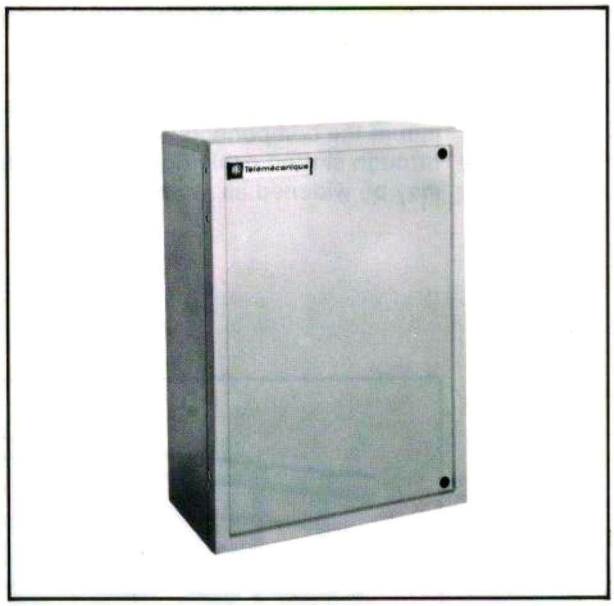
Using the dual action cutting and stripping tool the wire is cut to length and stripped simultaneously at both ends. The cable ends are more economical than crimped terminations and provide an important saving in labour costs. Their use requires no soldering, no crimping and no special tools as they are crimped automatically by the component terminal.

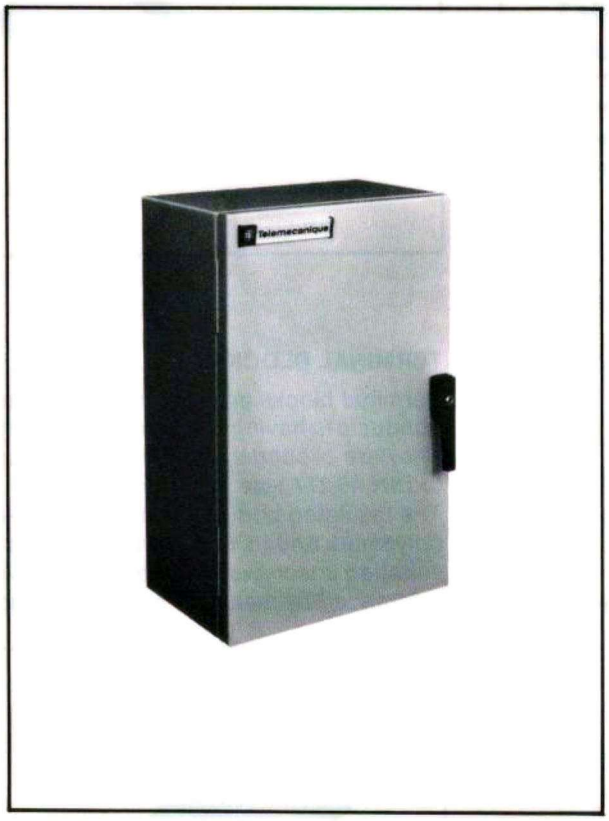
Equipment protection - Enclosures

All equipment can be mounted quickly and simply in metal enclosures, insulated enclosures or one or two door cabinets specially designed to resist the severest atmospheres encountered in industrial applications.

METAL ENCLOSURES

Of welded sheet steel construction with V-channel seal these enclosures meet industrial requirements. The panel is rapidly installed by means of studs, spacers and nuts supplied with the enclosure.





INSULATED ENCLOSURES

These are enclosures of fibreglass reinforced polyester especially resistant to the most corrosive atmospheres.
Classified as "double insulated" they are especially adapted for harsh operating conditions.
Installation of equipment is the same as for the metal enclosures.

CABINETS

These are of welded construction suitable for all industrial applications. On cabinets with 3 or 4 doors, removable door frames provide complete accessibility to the inside of the cabinet for easy installation of equipment.
The frame is mounted by means of sliding clamps onto channel within the cabinets.

standardization of electrical schematics

Graphic symbols and equipment identification references recommended for use in this publication comply with:

— recommendation IEC 113-2 (1971 edition); 117 and especially 117-3 (1976 edition);

— European standard CENELEC EN 50-005;

— certain other standards, such as DIN standards.

These recommendations define the rules, graphic symbols and numeric or alphanumeric references which should be used in marking equipment and designing schematics.

The observation of these rules leads to a standardization which:

— promotes the internationalization of symbols and references;

— eliminates the risks of error and confusion;

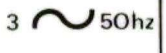
— simplifies installation and maintenance.

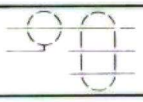
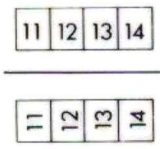
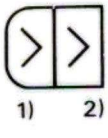
standardization of schematics

SYMBOLS

Each element of a device (coil, pole, auxiliary contact, etc.) is represented by a symbol which must strictly conform to the rules.
This permits the reader of a schematic to understand the functions of the various components and to understand the operation of the equipment.

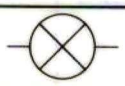
The graphic symbols shown below reflect the most recent trends. Some are followed by an asterisk (*) to indicate symbols long used for certain Telemecanique products having special characteristics and which for this reason are not officially standardized but which are in current use.

TYPE OF SUPPLIES, CONDUCTORS, TERMINALS AND CONNECTIONS	
Alternating current	
Direct current	
Rectified supply	
3-phase alternating current 50 Hz	
Earth	
Chassis connection	
Protective earth	
Conductor, auxiliary circuit	
Conductor, main circuit	
3 conductors	
Single line representation	
Neutral conductor	
Protective conductor	

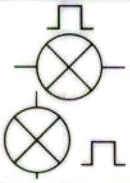
Screened conductors	
Twisted conductors	
Crossing with no connection	
Crossing with connection (junction)	
Tap	
Terminal	
Terminal strip	
Male plug	
Female socket	
Plug and socket	
Coupled connectors 1) moving part, male 2) fixed part, female	

SIGNALLING

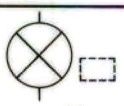
indicator light



Flashing light

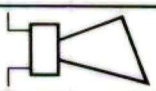


To specify



Colour:		Type:	
Red	C2	Neon	Ne
Orange	C3	Sodium vapour	Na
Yellow	C4	Mercury	Hg
Green	C5	Halogen	I
Blue	C6	LED	EL
White	C9	Fluorescent	FL
		Infrared	IR
		Ultraviolet	UV

Horn



Bell

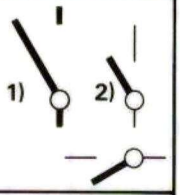
Siren

Buzzer

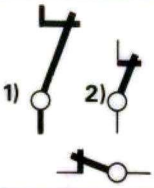
CONTACTS

Movement of contacts is as follows: from left to right and from bottom to top; the diagram always shows the rest (de-energized) position.

"Make" contact (N/O)
(general symbol)
1) main 2) auxiliary

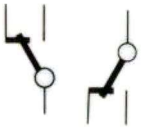


"Break" contact (N/C)
(general symbol)
1) main 2) auxiliary

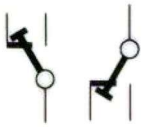


Changeover contact with open neutral position

Changeover break before make contact



Changeover make before break contact

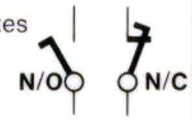


Fleeting contact

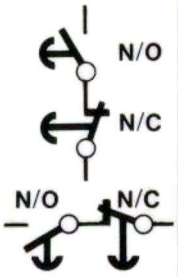
- closing momentarily on energization

- closing momentarily on de-energization

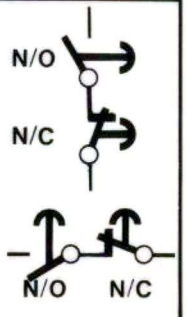
Delayed . . . .*. . . . contact (operates after the other contacts of the device)
* N/C normally closed
N/O normally open

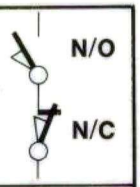


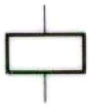
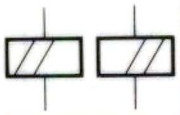
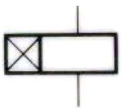
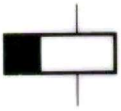
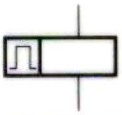
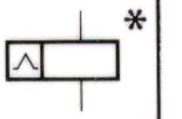
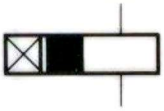
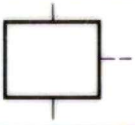
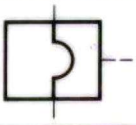
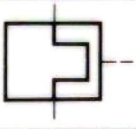
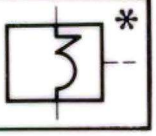
. . . .*. . . . contact delayed on energization
* N/C normally closed
N/O normally open

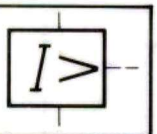
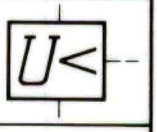
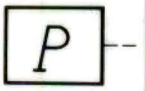
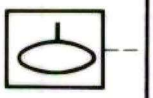


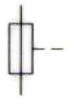
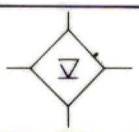
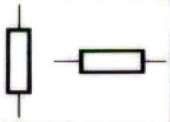
. . . .*. . . . contact delayed on de-energization
* N/C normally closed
N/O normally open

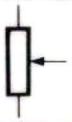
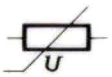
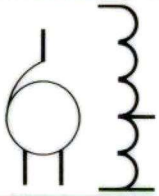


Selector switch (general symbol) Contact N/C normally closed N/O normally open	
4 position single pole switch with diagram showing position	
Switch (general symbol)	
Disconnect switch	
Isolator	
Switchfuse	
Circuit breaker	
Contactor (N/O pole)	
Contactor (N/C pole)	

CONTROL AND MEASURING COMPONENTS	
Coil	
- with 2 windings (single representation)	
- with 2 windings (separated representation)	
- delayed on energization	
- delayed on de-energization	
- of a flasher relay	
- of a fleeting relay	
- delayed on energization and de-energization	
Measuring relay (general symbol)	
- magnetic overcurrent type	
- thermal overcurrent type	
- thermal magnetic overcurrent type	

- overcurrent type	
- undervoltage type	
- pressure actuated type	
- actuated by fluid level (float type)	

MISCELLANEOUS COMPONENTS OR EQUIPMENT	
Fuse	
Striker fuse	
Rectifier	
Bridge rectifier	
Thyristor	
Capacitor	
Battery	
Resistor	

Shunt	
Inductor	
Potentiometer	
Separating line	
Variable: intrinsically linear	
Intrinsically non-linear	
Variable: adjustable linear	
Adjustable non-linear	
Variable with predetermined adjustable setting	
Non-linear resistor	
Voltage transformer	
Autotransformer	

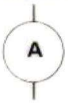
Current transformer

Lightning conductor

Starter

e.g. star delta starter

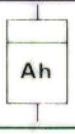
Indicating device (general symbol)

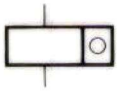
- ammeter 

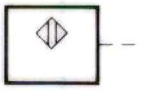
Recording device (general symbol)

- recording ammeter

Counter, meter

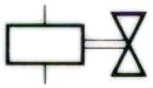
- ampere-hour meter 

Pulse counter 

Proximity detector 

Clock

Valve

for example: solenoid valve 

Brake

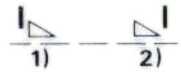
- with brake applied

- with brake released

MECHANICAL CONTROLS

Mechanical, pneumatic link

Latching device

(1) latched (2) unlatched 

Automatic return

Non-automatic return

- set

Mechanical interlock

Manual operator (general symbol)

- by push button (spring return)

- by handle (spring return)

- rotary (with latch)

- mushroom head

- by hand-wheel

- by pedal (foot switch)

- with limited access

- by lever

- by lever with handle

- by key

- by crank

Latching by push button with automatic unlatching *

Control
- by roller

- by cam and roller

- by electric motor

- pneumatic or hydraulic

(1) single acting
(2) double acting

Operation - to the right

- to the left

- in both directions

Rotation - forward direction

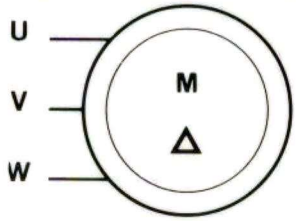
- reverse direction

- in both directions

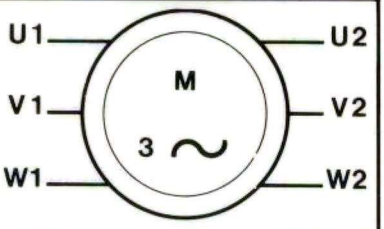
- limited in both directions

ELECTRIC ROTATING MACHINES

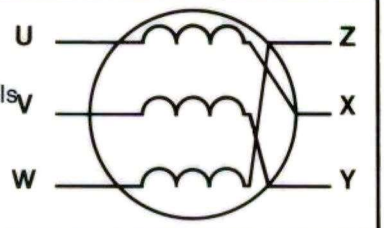
Three phase squirrel cage induction motor



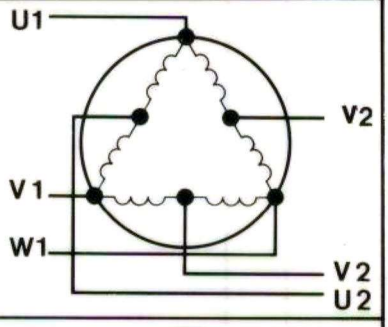
- 2 separate stator windings



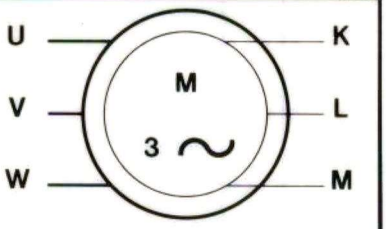
- 6 output terminals (star delta connection)



- Pole change (2 speed motor)

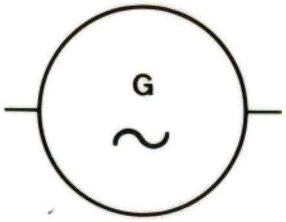


Three phase slipring induction motor

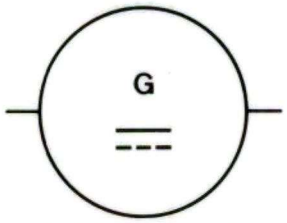


Shunt (1)
Series (2)
excitation winding

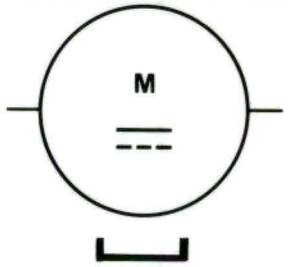
A.C. alternator



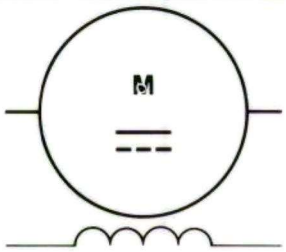
D.C. generator



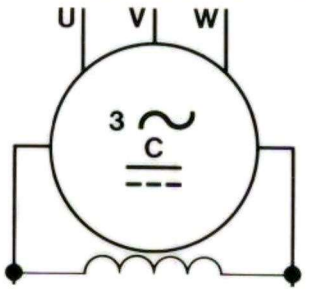
Permanent magnet motor



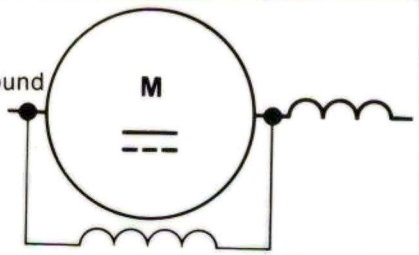
Separately excited d.c. motor



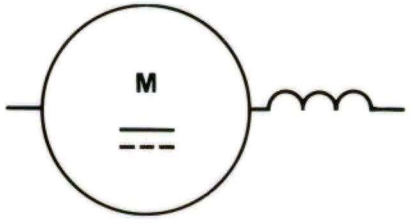
Rotary converter (three phase/d.c.) shunt excitation



Compound wound d.c. motor



Series wound d.c. motor



REFERENCING ON A CIRCUIT DIAGRAM

The components of a control panel are identified by letters followed by a number as shown in the chart below.
Example: a single contactor KM1; several contactors, identical or not; KM1, KM2, KM3, etc.

CHART I - Classification by reference letters.

REFE-RENCE	TYPE OF EQUIPMENT	EXAMPLES
A	Assemblies and subassemblies (standard)	Amplifier, speed controller, programmable controller.
B	Transducers of a non-electric quantity into an electric quantity (or vice versa)	Thermocouple, photoelectric cell, dynamometer, pressure switch, thermostat, proximity dectector.
C	Capacitors	
D	Timers, storage devices	Recorder, magnetic storage.
E	Miscellaneous equipment	Lighting, heating; equipment not specified in this chart.
F	Protection devices	Fuses, lightning conductors, overcurrent relay, overvoltage relay.
G	Generators (for power supply)	A.C. or D.C. generator, rotary frequency converter, battery.
H	Signalling devices	Warning devices, visual or audible.
J		
K	Relays and contactors	(in complex equipment, use KA and KM)
KA	Auxiliary contactors, relays	Auxiliary time-delays on contactors, all types of relays.
KM	Main contactors	
L	Inductances	Induction coil, choke coil.
M	Motors	
N	Subassemblies (non-standard)	
P	Meters, test devices	Meter, recorder, counter, timing devices.
Q	Mechanical connecting devices for power circuits	Circuit breaker, isolator.
R	Resistors	Variable resistor, potentiometer, rheostat, thermistor.
S	Mechanical connecting devices for control circuits	Push button, limit switch, selector switch.
T	Transformers	Voltage transformer, current transformer.
U	Converters	Frequency converter, inverter, rectifier.
V	Electronic valves, semi-conductors	Valves, gas tube, discharge tube, diode, transistor, thyristor, rectifier.
W	Terminals, plugs, sockets	Plug and socket, clips, test plug, terminal board.
Y	Electrically actuated mechanical devices	Brake, clutch or coupling, pneumatic solenoid valve, electromagnet.
Z	Corrective loads	Balancing network.

CHART II -

EQUIPMENT	REFE-RENCE
Alternator A.C. generator	G
Ammeter	P
Amplifier	A
Anemometer	B
Assembly, sub-assembly	A
Audible alarm, horn, etc.	H
Auxiliary contactor	K, KA
Auxiliary relay	K, KA
Battery, battery cell, dry cell	G
Cable	W
Capacitor	C
Circuit breaker	S
Clock elapsed time meter	P
Controller	S
Corrective load filter	Z
Current transformer	T
Clutch or coupling	V
Demodulator	U
Diode bridge rectifier	V
Diode	V
Disc or tape recorder	D
Electrically actuated mechanical device	Y
Electric brake	Y
Electric dynamometer	B
Electromagnet	Y
Encoder	U
Filter	Z
Foot switch	S
Fuse	U
Fuse	F
Generator	B
Heater	U
Indicating device	P
Inductance	L
Induction coil, choke coil	L
Inverter	U
Isolator	Q
Lamp	E
Latching relay	K, KA
Lighting	E
Lightning conductor	F
Limit switch	S
Magnetic overload relay	F
Manometer, pressure switch	B
Mechanical connecting device for control circuits	S

EQUIPMENT	REFE-RENCE
Mechanical connecting device for power circuits	Q
Memory storage device	D
Meter measuring device	P
Miscellaneous equipment	E
Monostable trigger, flip flop	D
Motor	M
Overvoltage	F
Photoelectric cell	B
Pilot light	H
Plate, panel (non standard)	N
Plug	X
Position switch	S
Potentiometer	R
Power contactor	K, KM
Pressure detector	B
Protection relay	F
Protective device	F
Proximity detector	B
Proximity switch	S
Pulse counter	P
Push button	S
Push button station	S
Rack (non standard)	N
Recorder	P
Rectifier	K, KA
Resistor	R
Rotation detector	B
Selector switch	S
Semi-conductor	V
Shunt	R
Signalling device	H
Socket outlet	X
Storage device	H
Tachogenerator	B
Temperature detector	B
Terminal board or strip	X
Thermal magnetic overload relay	F
Thermal overload relay	R
Thermistor	R
Thermostat	B
Thyristor	V
Time delay relay	K, KA
Time delay on contactor	K, KA
Transducer	B
Transformer	T
Variable resistor	R
Varistor	R
Voltmeter	P
Voltage transformer	T
Watt hour meter	P

Marking of component terminals

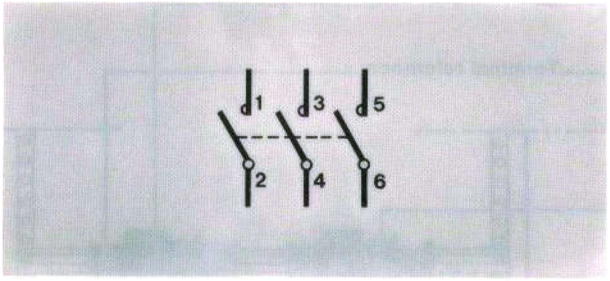
The marking of component terminals permits large savings to be made in the layout of the schematic and in equipment wiring. It also aids testing, trouble shooting and maintenance. Wiring with the aid of a schematic diagram, as explained on page 176, is an example. In defining equipment terminal references, Telemecanique has followed the essential principles of International standardization.

MARKING OF TERMINALS

The references shown are those on the terminals or on the rating plate of the equipment.
Alphanumeric or numeric references are given to each type of contact; main, auxiliary, instantaneous or time delay.

Main contacts (contactors, isolators and overload relays)

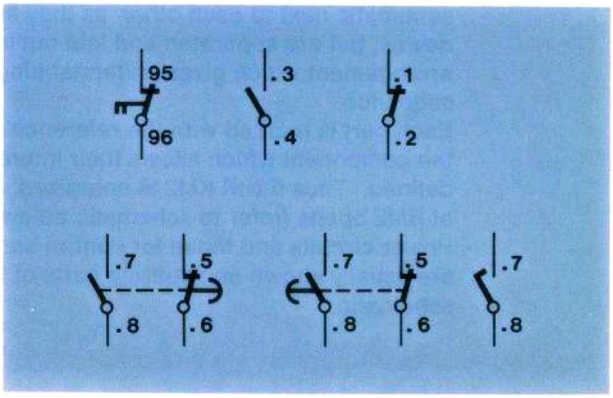
Their terminals are referenced with a single number
from 1 to 6 for three pole
from 1 to 8 for four pole
from 1 to 10 for five pole.
Odd numbers are placed at the top and numbering progresses from top to bottom and from left to right.



On small contactors, the fourth pole of a four pole contactor is an exception to this rule; its terminals bear the same references as those of the N/O auxiliary contact whose place it occupies.

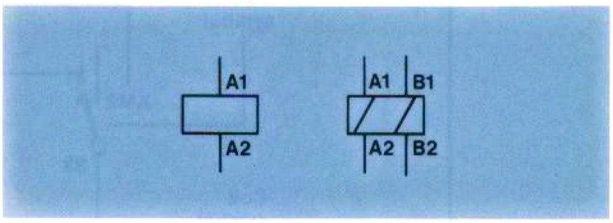
Auxiliary contacts

Terminals of auxiliary circuits are referenced by two-digit numbers.
The second digit indicates the function of the auxiliary contact:
1 and 2: normally closed (N/C) contact
3 and 4: normally open (N/O) contact
5 and 6: normally closed contact (with special operation such as time delay)
7 and 8: normally open contact (with special operation such as time delay).
The first digit indicates the physical position of each contact of the component. Number 9, and 0 if necessary, is reserved for auxiliary contacts of overload relays, followed by the function 5 and 6 or 7 and 8.



Coils

References are alphanumeric, with the letter coming before the number:
— Operating coil of a contactor: A1 and A2 (A and B are used at present).
— Operating coil of a contactor, with two windings: A1 and A2; B1 and B2.



REFERENCING OF TERMINALS ON TERMINAL BOARDS

Control circuit

In each group of terminal, numbers increase from left to right from 1.

Power circuit

Conforming to the latest International standards, referencing is as follows:
— Power supply: L1 - L2 - L3 - N - PE.
— To a motor: U - V - W; K - L - M.
— To starting resistances: A - B - C, etc.

Schematic diagrams

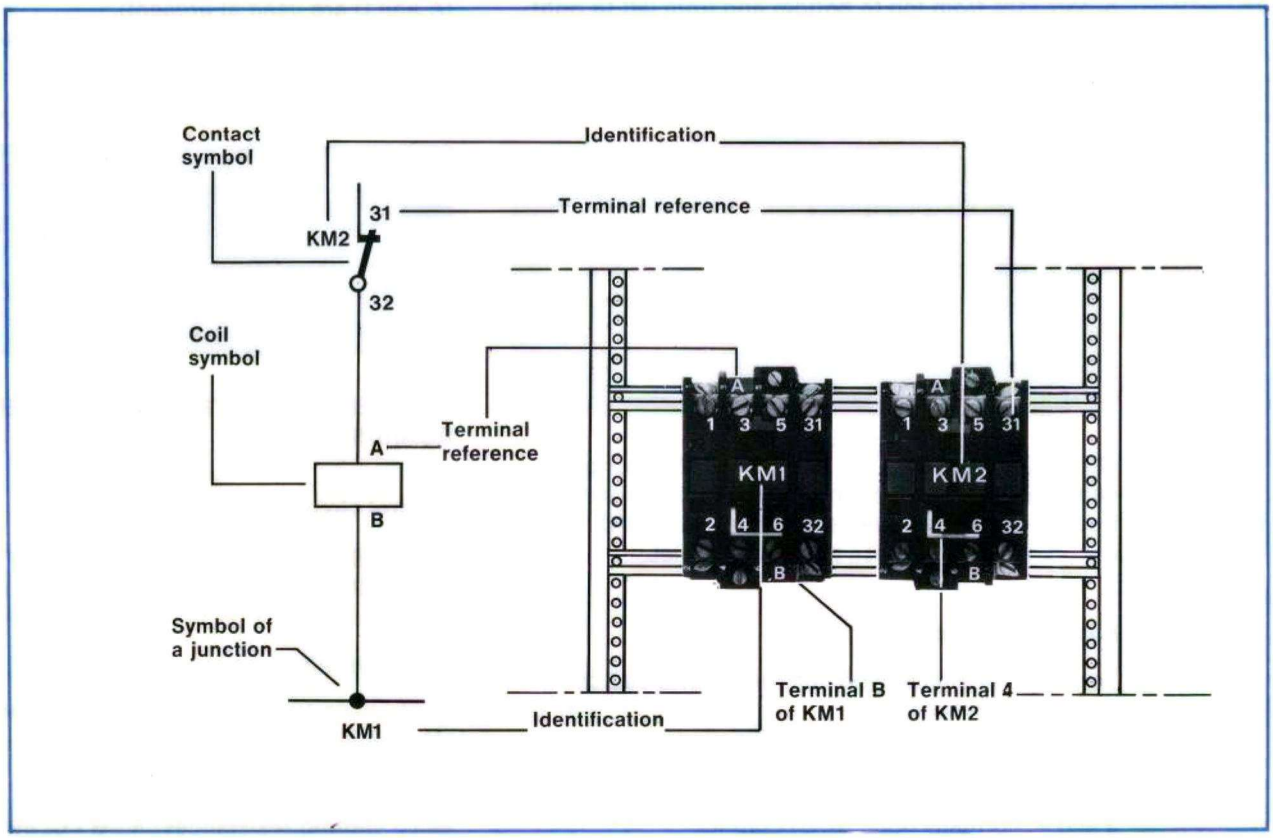
This explanatory schematic diagram is designed te help understand the operation of the equipment; it should also be an aid to wiring and trouble shooting when necessary.

The various parts of the component (coil, pole, auxiliary contact, etc.) are not shown on the schematic next to each other, as they are in the device, but are separated and laid out in an arrangement which gives understanding of the sequence.
Each part is marked with the reference number of the component which allows their interaction to be defined. Thus if coil KM2 is energized, contact 31-32 of KM2 opens (refer to schematic below).
Power circuits and those for control and signalling are usually shown on separate parts of the schematic.

REFERENCING RULES

As mentioned above:
- all the components in a control panel are identified by an alphanumeric code (page 69);
- all terminals of the components are marked with a reference (page 71).

The identification number should be located:
- for components: below the symbol;
- for contacts; on the left (vertical representation).



LOCATION ON THE SCHEMATIC DIAGRAM

This reference indicates the position on the schematic where the other parts of the same component are located. It is:
- written under the contact symbol and in line with the junction on the schematic;
- composed of the page number/line number with the line number being sufficient for all entries on the same page.

LAYOUT OF SCHEMATICS

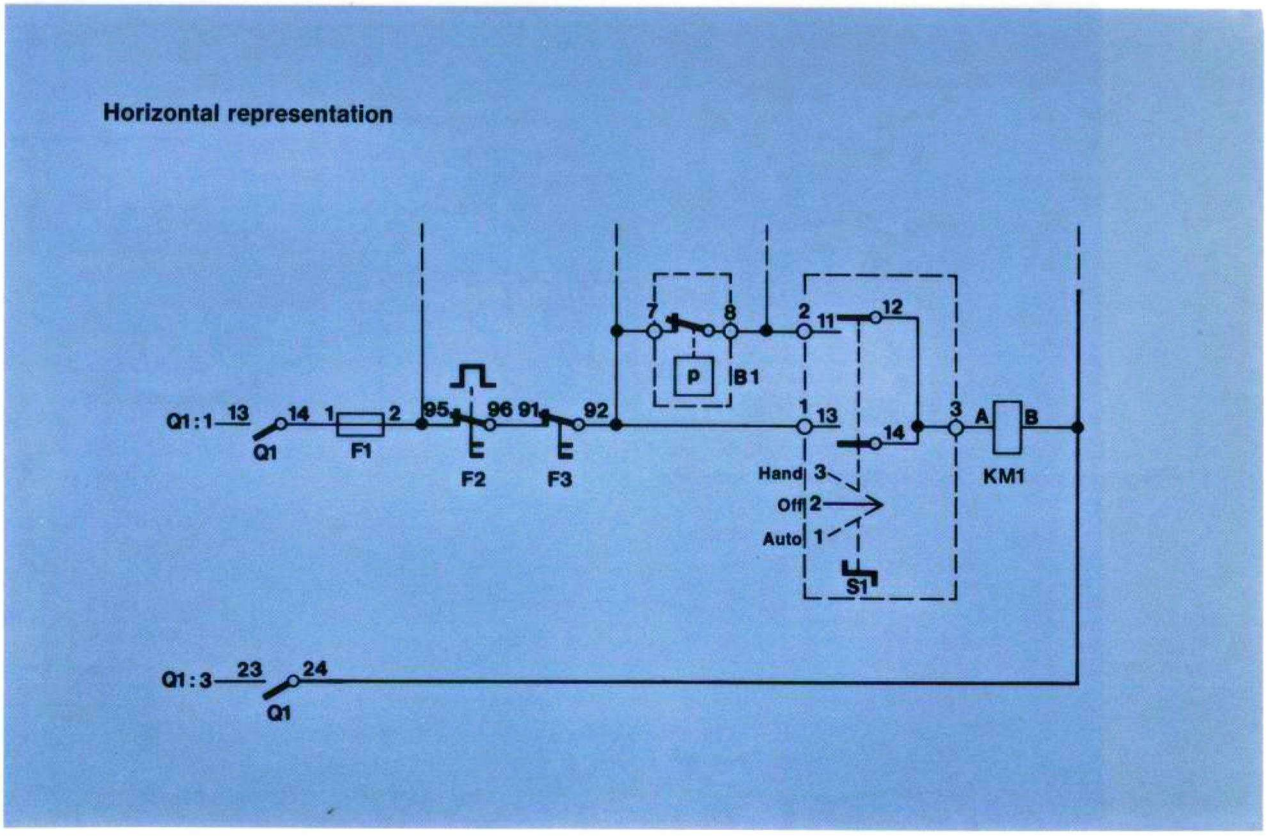
The power and control circuits are shown on separate parts of the schematic.

General layout of a circuit diagram

(See schematic on page 176)
At the top of the power circuit schematic horizontal lines represent the main supply and the various loads are placed on the branch lines. The control schematic is shown between two horizontal lines (page 176).

Representation of power circuits

These circuits are shown in single line form for simple cases or in multiline form for other cases (reversing starters, star-delta starters, two-speed starters, etc.).
In a single line representation the number of strokes which cross the line representing the supply indicates the number of similar conductors in the supply: for example, two for a single phase system and three for a three phase system (1).
In order to permit the user to determine the cross-section of the conductors, the electrical characteristics of each load are indicated either directly on the schematic or in a table.
Terminals of devices external to the equipment are also shown on the drawing.



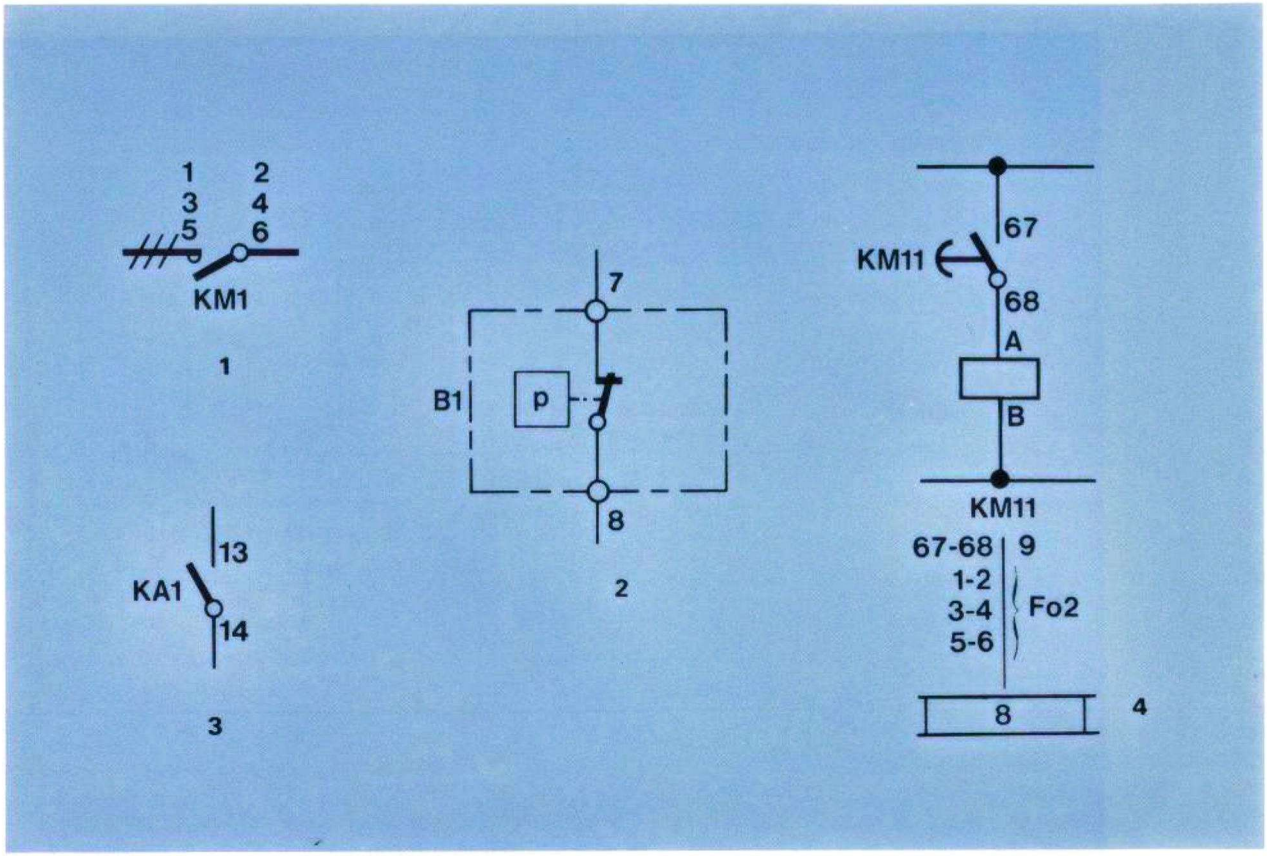
REPRESENTATION OF CONTROL AND SIGNALLING CIRCUITS

On a control diagram the symbols of coils of contactors, relays and other electrically controlled devices are laid out in the order corresponding to their energization in normal operation.
Two horizontal lines represent the power supply. The coils of contactors and the various loads, lamps, etc., are connected directly to the lower conductor. The other elements:
- auxiliary contacts,
- external control devices (buttons, limit switches, etc.), as well as the terminals are shown above the control element.

In order to distinguish the terminals from the device symbols they are represented by a circle of larger diameter. External devices are drawn inside a chain dotted outline which permits the installer to determine more easily the number of conductors required for their connection (2).

ADDITIONAL REMARKS

To improve the understanding of circuit diagrams, the letters and figures identifying a device and specifying its type are shown to the left whereas its terminal markings are shown to the right (3). In a horizontal layout the identification reference is placed below and the terminal markings above. With the devices grouped by function and in the logical sequential order of operation, their function as well as that of the group to which they belong are indicated. On complex schematics, when it becomes difficult to find all of the contacts of the same device, the diagram of the control circuit will include a numerical reference of each vertical line. Written below the coils are the numerical references of the contacts they actuate and the number of the vertical line on which they are located (4). If necessary, the page of the schematic is also given.



induction motors

The majority of machines are driven by alternating current three phase induction motors. This type of motor is used in most applications because of its lower cost, ruggedness and simplicity of maintenance.
It would therefore appear essential to review the principles of construction and operation of this type of motor and then describe and compare the principal methods of starting, speed regulation and braking which are associated with it.

starting, speed regulation and braking of induction motors

GENERAL

The induction motor contains two parts:

STATOR

This is the stationary part of the motor. It consists of a frame, to which is fixed a ring of high quality slotted steel laminations. Windings of appropriate section are distributed among these slots to form a set of windings which includes as many circuits as there are phases in the main supply.

ROTOR

This is the moving part of the motor. It is placed inside the stator and consists of steel laminations forming a cylinder keyed to the motor shaft. Among the most commonly used types are:

The squirrel cage rotor

• Single cage rotor

Conductors are wound in the slots near the outside of the cylinder and parallel with its axis and are connected at each end to a metal ring. The unit is similar to a squirrel cage from which the motor takes its name.

These motors have a relatively low starting torque and the starting current is much higher than the rated current.

• Double cage rotor

This rotor consists of two concentric cages, the outer one being of higher resistance than the inner one.

At the beginning of starting, with the flux being at high frequency, the induced currents oppose flux penetration into the inner cage and the torque produced by the outer cage is high and the current drawn is reduced.

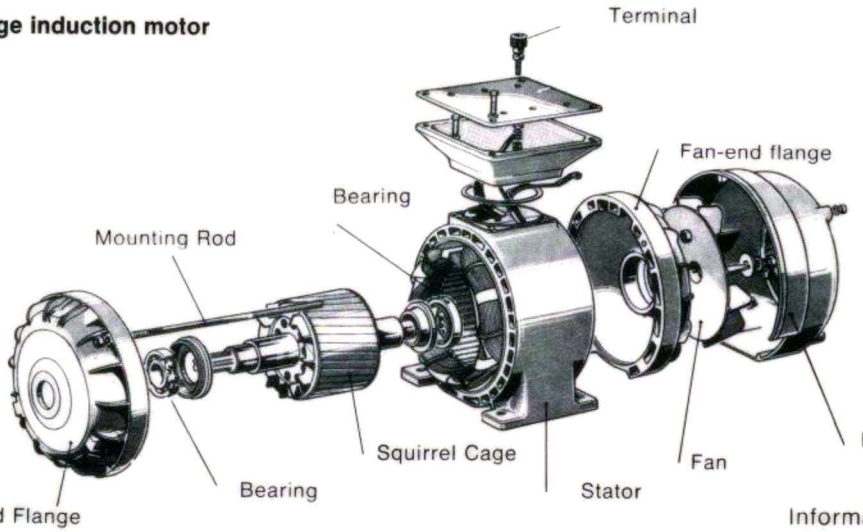
At the end of starting the frequency is reduced in the rotor and the passage of flux through the inner cage is easier; the motor then acts as if it were constructed with a single cage.

In steady state operation the speed corresponding to the rated torque is only slightly less than that of a motor with a single cage. The triple cage motor is also used when the starting torque is even greater and the current lower.

The Wound Rotor (slip ring) motor

Windings, identical to those of the stator, are wound in slots machined in the laminations forming the rotor which is usually three phase. One end of each winding is connected to a common point (star connection) and the free ends are connected to three copper rings, insulated from and fixed to the rotor. Carbon brushes connected to the starting device are held against the rings. Depending upon the value of resistance inserted in the rotor circuit, this type of motor can develop a starting torque up to 2.5 times the nominal torque and the starting current is in the same proportion to the nominal current.

Squirrel cage induction motor



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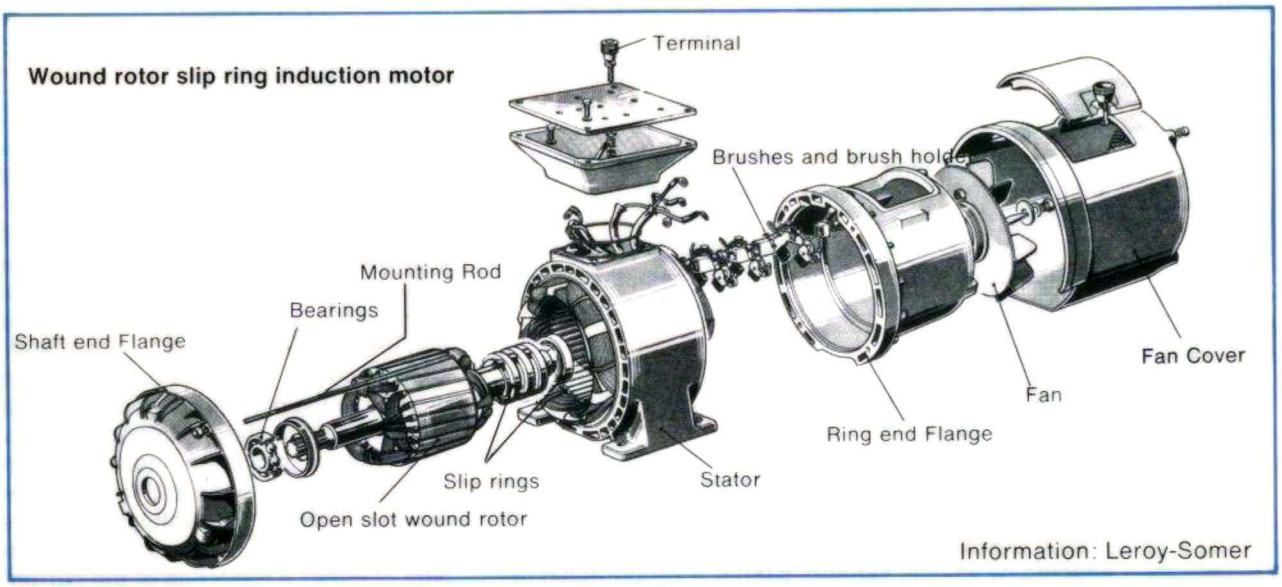
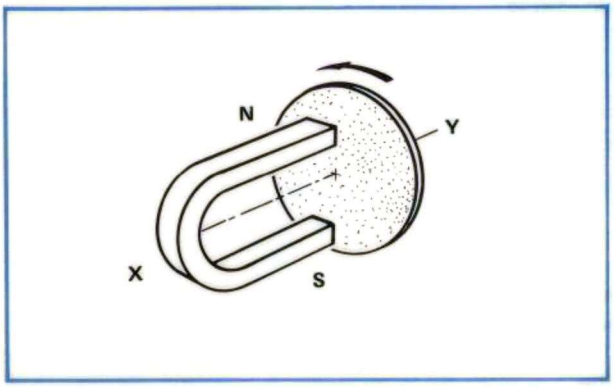
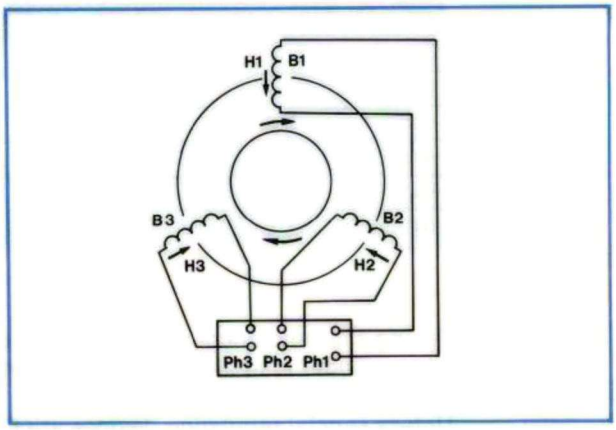


Principle of operation

The principle of operation of induction motors is based on the production of a rotating field: let us consider a permanent magnet NS and a copper disc mounted on an axis XY and capable of rotating on the axis.



When the magnet turns the magnetic field it produces also turns and sweeps the disc. Currents are then induced in the disc by the rotation of the magnetic field supplied by the magnet.
These currents react upon the field producing a driving torque of sufficient strength to overcome the opposing torque due to friction and cause the disc to rotate.
The direction of rotation, indicated by Lenz's law, tends to oppose the variation of the magnetic field which has created the currents. The disc is therefore driven in the direction of the rotating field at a speed slightly less than that of the field (slip speed).
If the disc turned at the same speed as the field (synchronous speed) there would be no induced currents and the torque exerted would be zero. It is because the speed of the disc (or rotor) is less than that of the rotating field that this type of motor is called "asynchronous".



The rotating field in three phase induction motors is produced by three fixed windings, spaced 120° apart, through which flow alternating currents also 120 electrical degrees apart. The three alternating fields that they produce combine to form a rotating field of constant magnitude.

THE SQUIRREL CAGE MOTOR

The metal bars forming the squirrel cage are cut by the rotating field produced by the stator, which gives rise to high induced currents and these currents interact with the rotating field to produce a motor torque which rotates the squirrel cage.

THE SLIPRING MOTOR

The rotor windings are connected by means of sliprings and brushes to a bank of three resistors in star connection.
The conductors, cut by the rotating field, produce induced rotor currents which flow through the resistors.
Since these currents are almost in phase with the electromotive forces which produce them, the starting torque is very high and the rotor is driven in the direction of the rotating field.

Speed of induction motors

The no load speed of induction motors is not affected by voltage variations but it is proportional to the frequency of the supply voltage and inversely proportional to the number of poles on the stator.
For industrial frequencies of 50 Hz and 60 Hz, the speed of the rotating field, or the synchronous speed, is as follows:

No. of poles	60 Hz	50 Hz
two	3,600 rpm	3,000 rpm
four	1,800 rpm	1,500 rpm
six	1,200 rpm	1,000 rpm
eight	900 rpm	750 rpm
ten	720 rpm	600 rpm
twelve	600 rpm	500 rpm

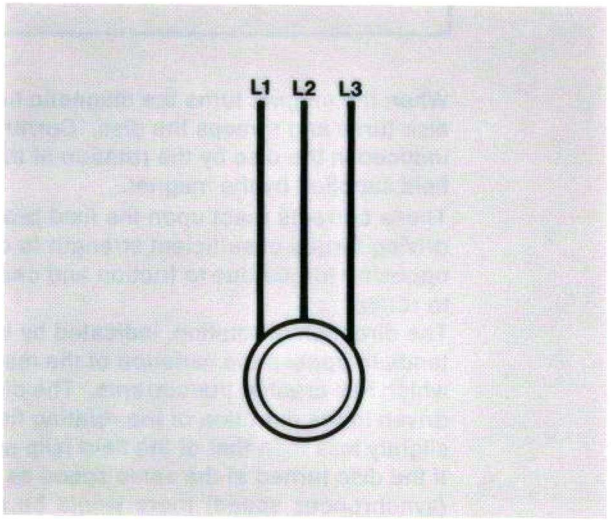
Taking slip* into account rotor speeds of induction motors under load are slightly less than those indicated above.
Unless special regulating devices are used, the speed of this type of motor under load varies little with variations of load or supply voltage.
Synchronous speeds other than those shown above, or higher than 3,600 rpm, can be obtained only by changing the frequency of the main supply.
(*) Slip: the difference between the speed of the stator rotating field, determined by the number of poles and the actual rotor speed. Slip can be expressed in revolutions per minute or more usually as a percentage of the synchronous speed.
Therefore it can be said that a motor has a nominal slip of 3% if it is a four pole motor (synchronous speed = 1,500 rpm) whose rotor turns at 1,455 rpm, when it develops the nominal torque.

STARTING OF SQUIRREL CAGE MOTORS

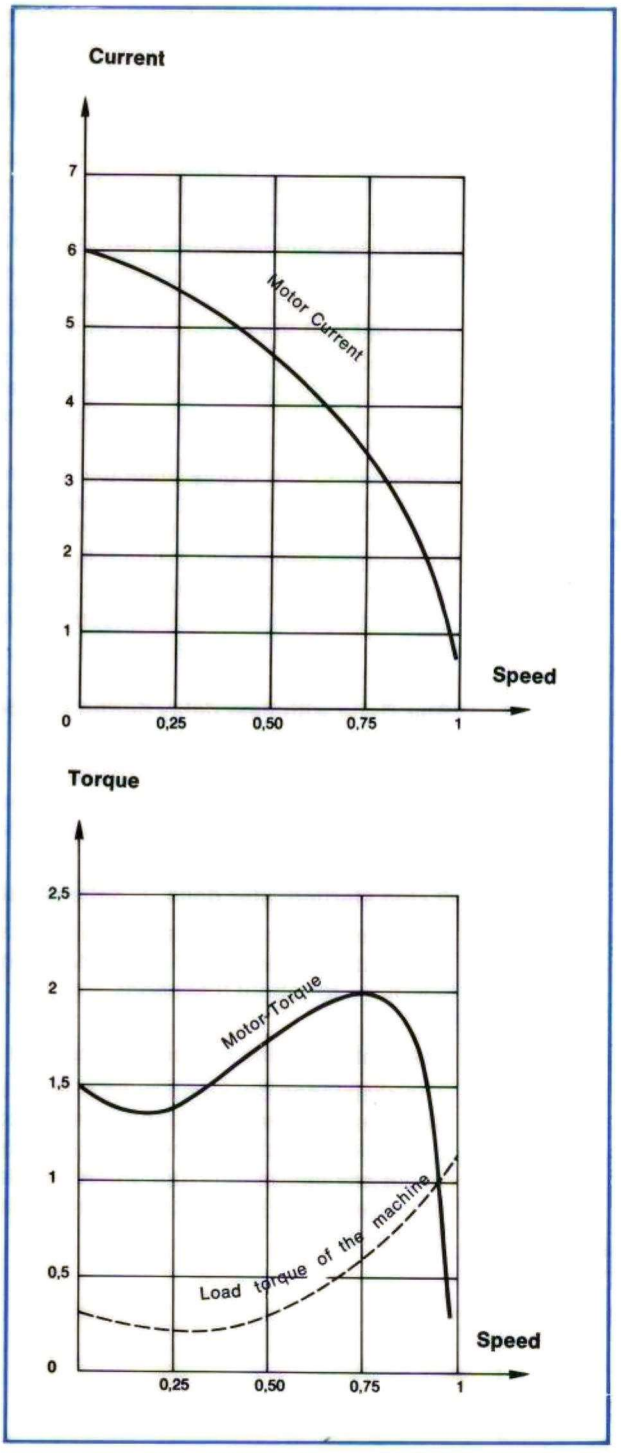
When voltage is applied to a motor the current surge in the main supply is high and can, especially if the cross section of the supply line is insufficient, cause a voltage drop capable of affecting the operation of other loads. To overcome these problems some power authorities forbid the use of direct starting induction motors above a certain power; others simply specify the ratio between the starting current and the rated current which is allowed.
Only a squirrel cage motor can be connected directly to the main supply with a simple device.
The ends of the stator windings are brought out to terminals and since the rotor characteristics have been determined once and for all by the manufacturer only the voltage at the stator terminals can be varied by various starting methods. On this type of motor a reduction of the current peak is automatically accompanied by a reduction in torque.

Direct on line starting

The stator of the motor is connected directly to the main supply and the motor starts with a high peak. This method is ideal as long as the peak current is acceptable and if the initial starting torque of the motor (determined by its rotor construction and usually about 1.5 Tn) is adequate to start the machine.



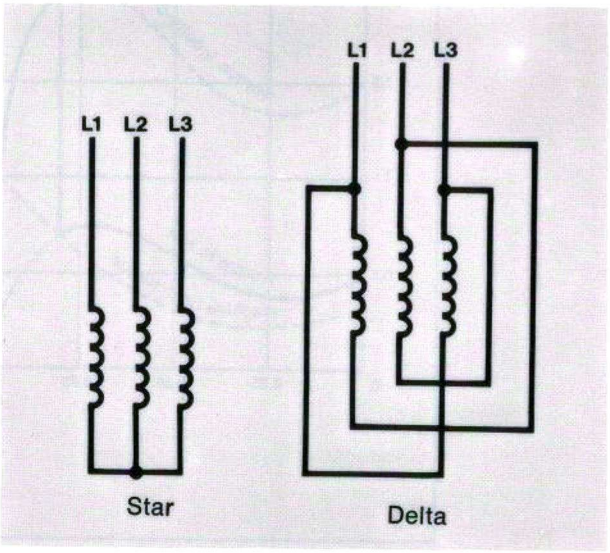
The current peak when the motor is energized is very high, of the order of 4 to 8 times the rated current. Torque during starting is always higher than the rated torque especially for modern motors with complex cages. It is a maximum when the motor reaches about 80% of its speed; at this moment the peak current is considerably reduced.

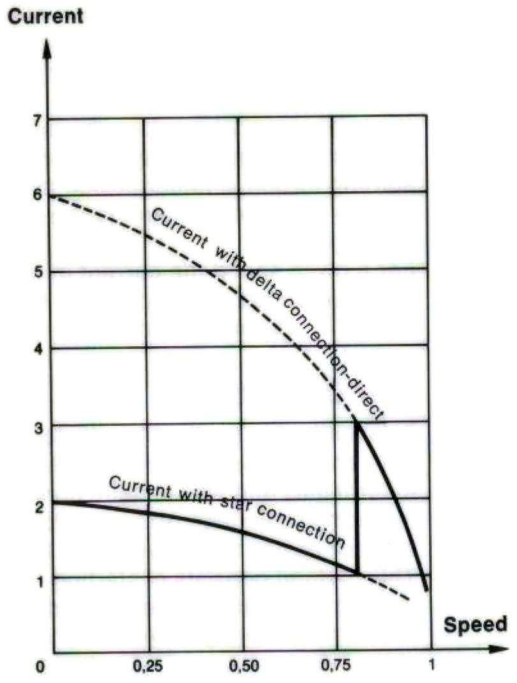


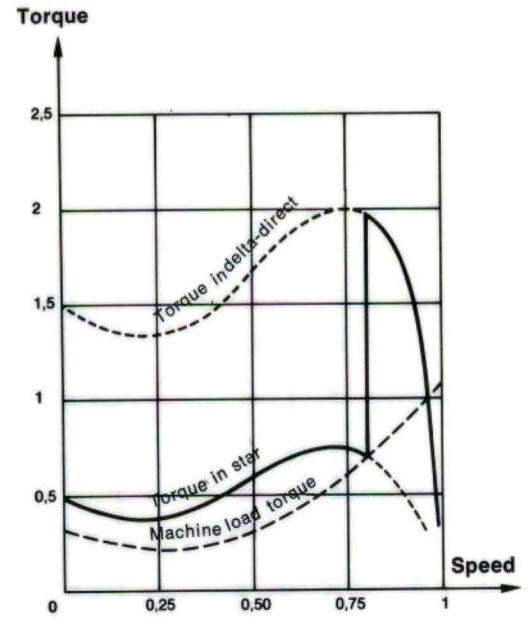
This arrangement permits the starting of machines, even at full load, if the supply authority allows the peak current required for starting so it is therefore particularly suitable for low and medium power machines.
However, with a starting torque of about 1.5 Tn this method is not recommended if starting should be smooth and progressive (certain elevators, hoists, conveyors, etc.).
If it is necessary to reduce the peak current when energizing a squirrel cage motor or to reduce its starting torque, another device must be used to reduce the stator voltage during the first step of the starting cycle.
For a given speed the current in the motor winding is then reduced in proportion to the voltage and the torque in proportion to the square of the voltage.

Star Delta starting

This method is applicable only to motors having both ends of the three stator windings brought out to terminals and whose delta connection corresponds to the mains voltage (example: for a 380 volt supply, a motor having 380 V Δ/660 V Y is required).
This method consists of starting the motor with star connected windings; the applied voltage is equal to the mains voltage divided by $\sqrt{3}$ or about 58% of the rated voltage. This voltage is constant during the entire first step. The torque, which is reduced by a ratio of the square of the voltage, is equal to one third of the torque furnished by a direct starting motor and the current in the supply line is reduced by the same amount.







The current in each winding is reduced by the ratio 0.58 and typical initial values are 2 In for current and 0.5 Tn for torque; star delta starting is therefore suitable for machines starting on no load or with low load.
In the second step the connection is changed from star to delta. Each winding then has the full main supply voltage applied and the motor resumes its normal running characteristics.
Motor torque remains low during the entire star connected period and the speed, stabilized at the end of this time, can be low if the load torque of the machine is high (for example in the case of a centrifugal machine).
This results in high peaks in current and torque during transition from star to delta. These considerations can lead to the star delta starter not being used with machines having centrifugal characteristics, especially beyond a certain power rating (for example 55 kW). Furthermore it should be noted that the current flow in the motor windings is not continuous as it is interrupted at the moment the star contactor is opened and then abruptly resumed, at the full mains voltage, when the delta contactor is closed.
Considering the highly inductive characteristics of the windings the transition to the delta connection is accompanied by very high transient current peaks. Above a certain power rating it is therefore advisable to reject the use of star delta starting or to use a variant permitting these transients to be limited. Among these variants:

Star Delta with time delay during star delta transition

Requires a machine with very low load torque and sufficient inertia to prevent a noticeable drop in speed during the time relay (usually 1 to 2 seconds).

3 step starting: star delta + delta resistance

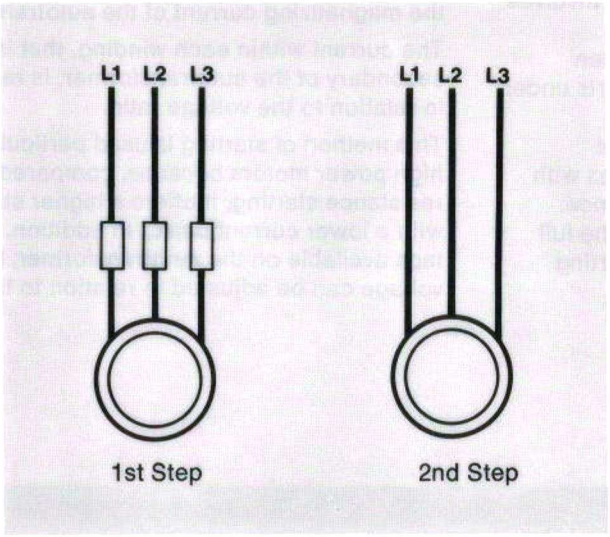
The interruption still exists but a resistance is connected in series with the delta connected windings for about 3 seconds.

Star Delta starting without interruption

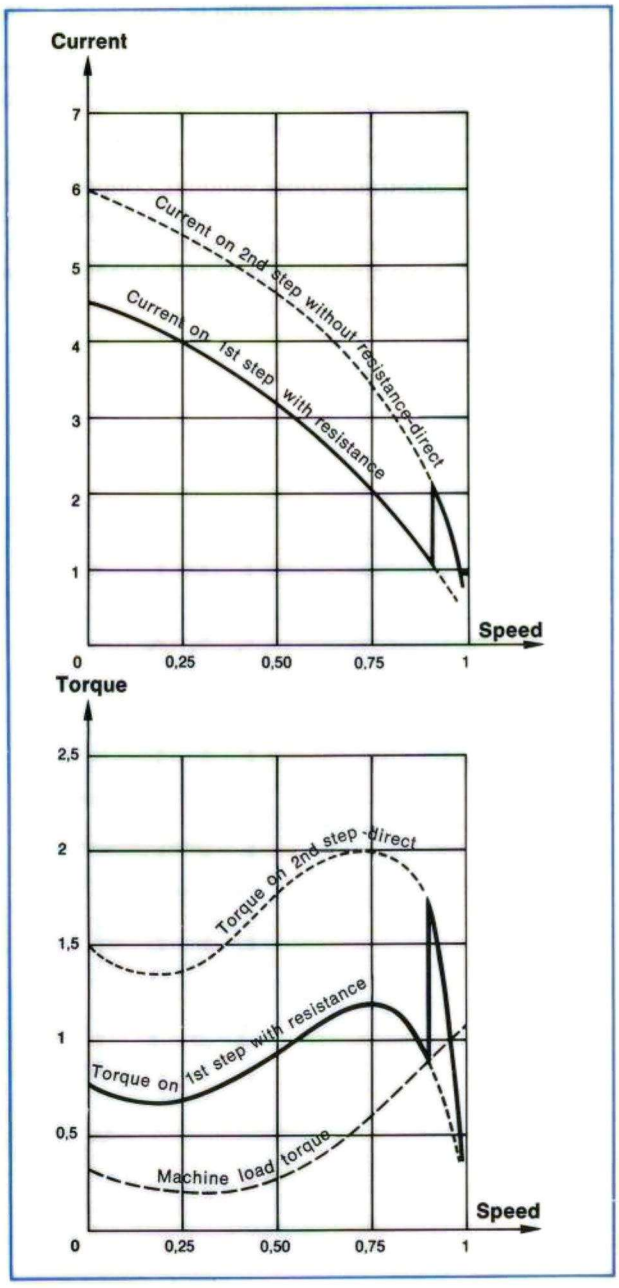
The resistance designed to be placed temporarily in series with the delta connection is connected just before the opening of the star contactor in order to avoid any circuit interruption. A detailed examination of these variants is beyond the scope of this publication.

Primary resistance starting

During the first step the supply voltage is reduced by resistance placed in series with each stator winding and the resistors are subsequently shorted out, usually at the same time.
Since the electrical connections of the windings are not modified during starting, the starting line current is reduced only in proportion to the voltage applied to the motor whereas the torque is reduced in proportion to the square of this reduction.



Starting torque is relatively low (typical value: 0.75 Tn) for a rather high peak current (typical value: 4.5 In).
The voltage applied to the motor terminals does not remain constant during the period of acceleration. The current which is a maximum when the motor is switched on drops as the motor accelerates; the voltage across the terminals of the resistors drops and the voltage at the motor terminals increases progressively. Since the torque is proportional to the square of the voltage the values of torque obtained are higher for a given initial torque than with a system delivering a lower voltage of fixed value. The adjoining stator and star delta curves drawn for initial starting torques of the same order, clearly illustrate this improvement.
With star delta starting of the motor driving a machine of the centrifugal type the speed reached at the end of the first step is about 80% of the rated speed and transition to the second step is accompanied by current surges.
With primary resistance starting the transition to full voltage occurs at a much lower speed with much lower peaks so acceleration is progressive and smooth. In addition it is possible to change the starting current and torque by changing the resistance.
Therefore primary resistance starting is well suited to starting machines with increasing load torque or torque around half the rated torque including high inertia machines.



However this type of starting presents a problem : for a given torque reduction, for example in the ratio kT, it also reduces the current peak at starting only by the rather low ratio $\sqrt{kT}$ (whereas this current peak is reduced by a ratio close to kT by the star delta or autotransformer systems).
On the other hand the presence of a large and practically non-inductive resistance considerably reduces the amplitude of the current peak during the initial state, which is often a major advantage.

Autotransformer starting

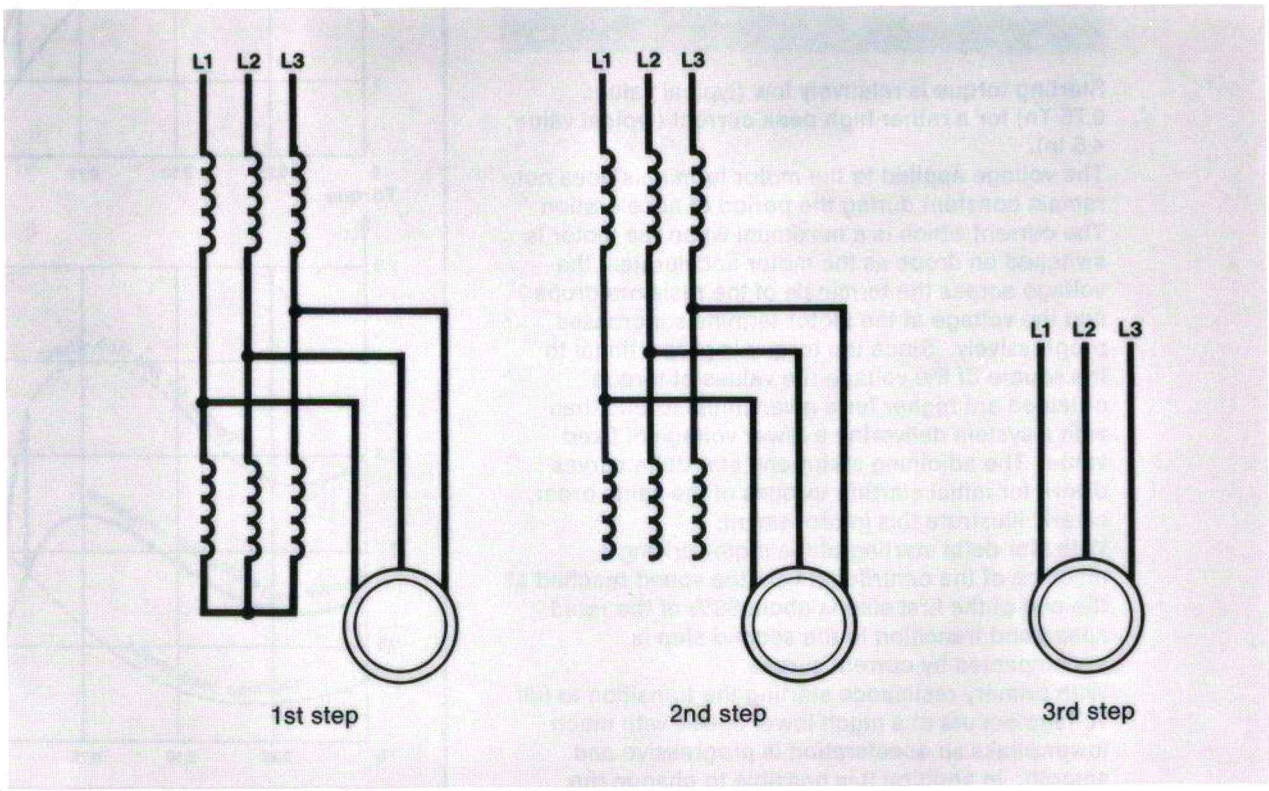
The motor is supplied with reduced voltage by means of an autotransformer which is switched out of the circuit when starting is completed. Starting involves three steps:
— star connection of the autotransformer then closing of the line contactor. The motor starts under reduced voltage.
— opening of the neutral point. A part of the autotransformer winding, connected in series with each phase of the stator, acts as an inductance.
— a third contactor connects the motor to the full main supply voltage and causes the two starting contactors to open.

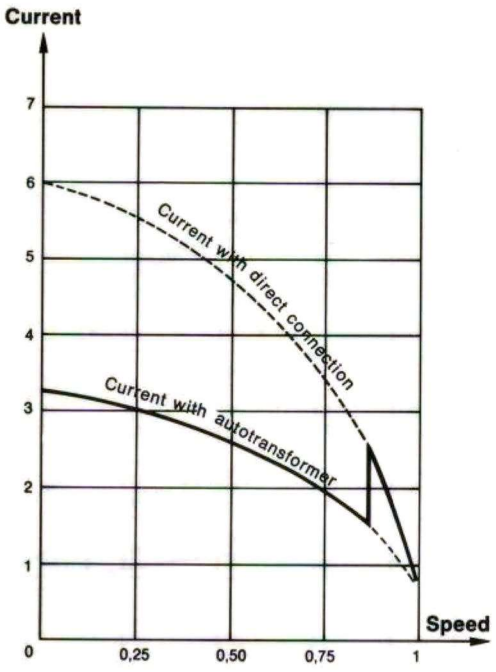
With this device the motor is never separated from the main supply and the current is not interrupted so transients are eliminated. However in order to avoid too great a slowdown on the second starting step the inductance of the autotransformer windings should be low and matched to the motor. To obtain this suitable value of inductance it is necessary to provide an autotransformer whose magnetic core contains an air-gap. The second step is mainly intended to damp the electrical transition and is usually made very short (time of contactor changeover).

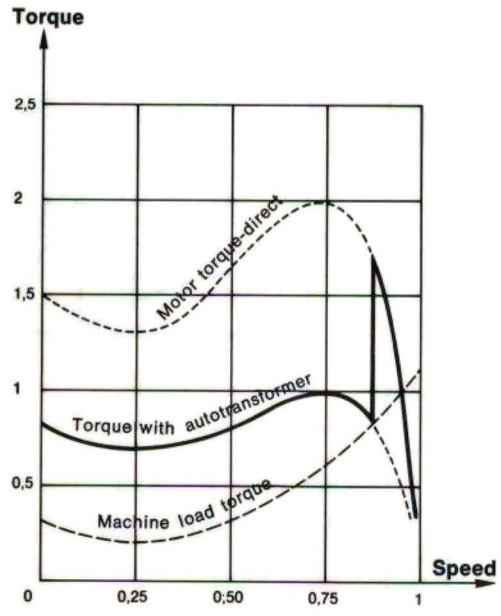
During the first step the torque is reduced in proportion to the square of the voltage and the line current by a similar proportion, slightly higher due to the magnetizing current of the autotransformer.

The current within each winding, that is to say in the secondary of the autotransformer, is reduced only in relation to the voltage ratio.

This method of starting is used particularly for high power motors because, compared with primary resistance starting, it offers a higher starting torque with a lower current peak. In addition, with several taps available on the autotransformer, the starting voltage can be adjusted in relation to the load.







STARTING OF SLIPRING MOTORS

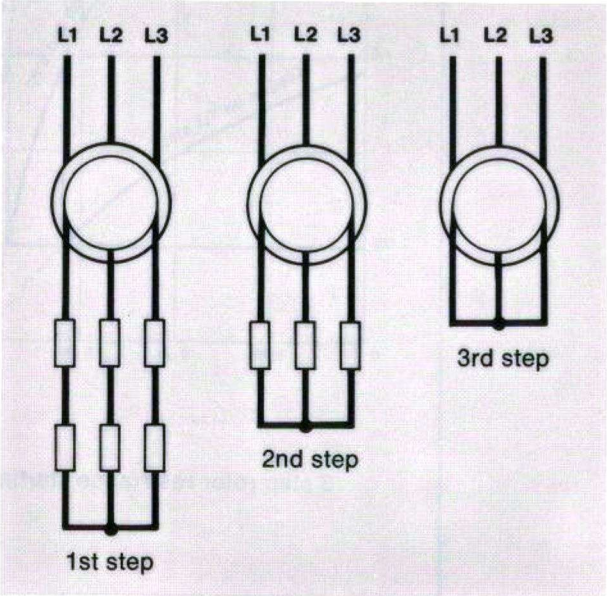
Rotor resistance starting

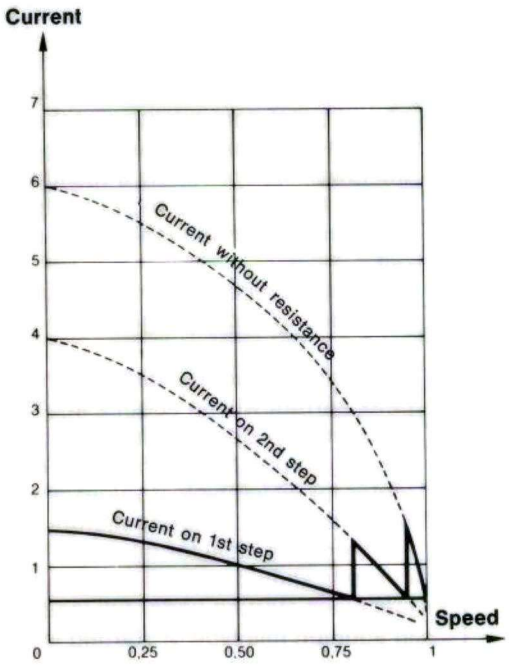
A slipring motor cannot start in one step because of unacceptable torque and current peaks: while the stator is supplied with the full main voltage it is necessary to insert in the rotor circuit a bank of resistances which are then shorted out progressively. Calculation of the resistance inserted in each phase allows exact determination of the torque-speed curve: for a given torque, the higher the resistance the lower the speed. As a result the total resistance should be inserted at motor switch-on and full speed is attained when the resistance is entirely shorted out.

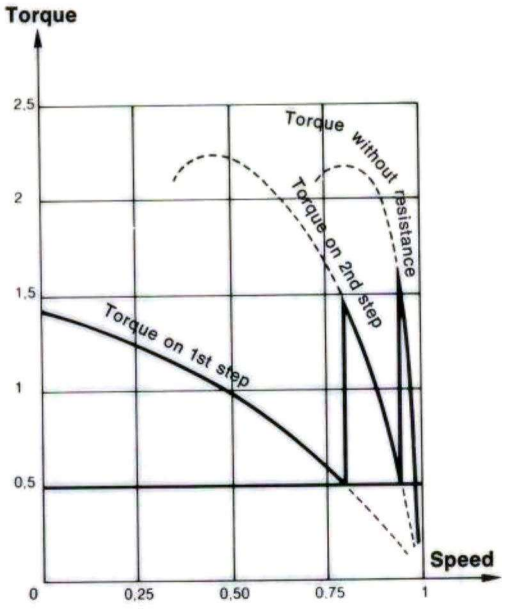
Current is proportional to the output torque or, at least, is only slightly higher than that theoretical value.

For example, for an initial starting torque of 2 Tn the peak current will be about 2 In. This peak is therefore considerably lower and the maximum starting torque higher than with a squirrel cage motor for which typical values are of the order of 6 In with 1.5 Tn. Slipring motors with rotor starting are therefore ideal for all cases in which peak currents should be held to a minimum and for machines starting under full load.

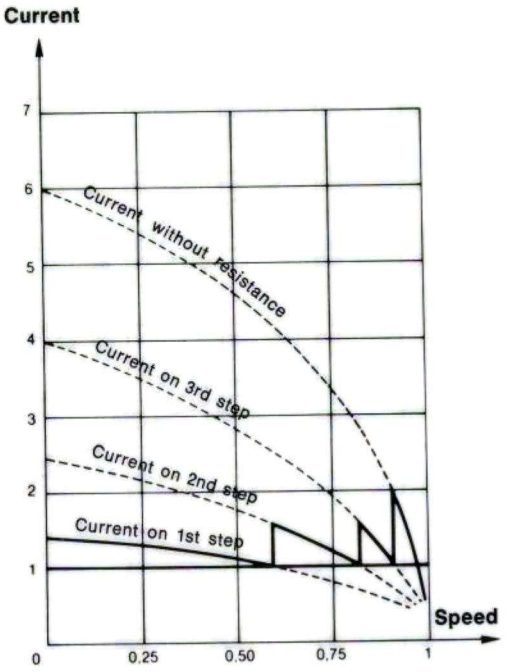
In addition this type of starting is extremely flexible because it is easy to match the number and shape of the curves representing successive rotor steps to mechanical and electrical requirements (load torque, rate of acceleration, maximum current peak, etc.).

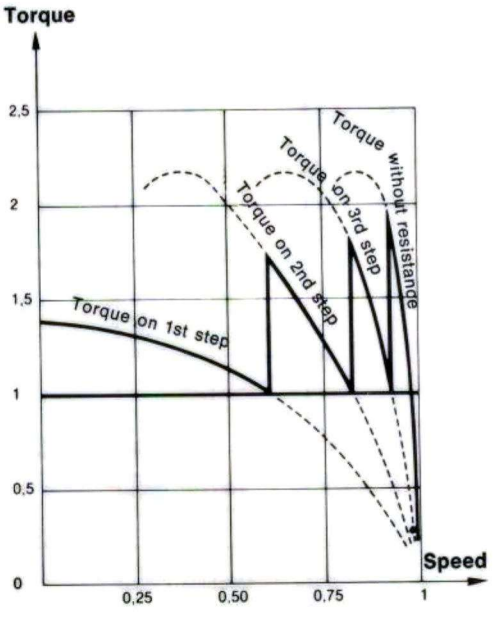






3 step rotor resistance starting





4 step rotor resistance starting

SUMMARY OF CHARACTERISTICS OF VARIOUS STARTING METHODS

	Squirrel cage motors				Slipring motors
	Direct on line starting	**Star delta starting**	**Primary resistance starting**	**Starting with auto-transformer**	**Rotor starting**
Initial starting current	4 to 8 In	1.3 to 2.6 In	4.5 In	1.7 to 4 In	< 2.5 In
Initial starting torque	0.6 to 1.5 Tn	0.2 to 0.5 Tn	0.6 to 0.85 Tn	0.4 to 0.85 Tn	< 2.5 Tn
Advantages	Economical and rugged squirrel cage motor • Simple inexpensive starter. • High starting torque.	• Relatively inexpensive starter.	• Possibility of adjusting starting values. • No break in line supply during starting.	• Good torque/current ratio. • Possibility of adjusting starting values. • No break in line supply during starting.	• Very good torque/current ratio. • Possibility of adjusting starting values. • No break in line supply during starting.
Disadvantages	• Very high starting current and torque. • Does not permit slow and progressive starting.	• Low starting torque. • No adjustment possible. • Break in line supply when changing connections. • 6 terminal motor required.	• Small reduction in starting peak. • Requires resistors.	• Requires a costly auto-transformer.	• Slipring motor more expensive. • Requires resistors.
Usual starting time	• 2 to 3 seconds	• 3 to 7 seconds	• 7 to 12 seconds	• 7 to 12 seconds	• 2.5 seconds for 3 steps • 5 seconds for 4 and 5 step
Typical applications	• Small machines even starting on full load.	• Machines starting at no load. • Small fans and centrifugal pumps.	• High inertia machines with no special torque or starting current problems.	• High power or high inertia machines when the reduction of current peak is an important consideration.	• Machines starting at full load; progressive starting, etc.

HOW TO CHOOSE A STARTER FOR AN A.C. MOTOR

1 - Determine if the peak starting current should be reduced

a) The installation is supplied with the necessary mains voltage by the supply authority.

Comply with the regulations of the supply authority which fixes the power limit at which a motor can be started without reduction of the peak.

b) The installation is supplied by a stepdown power transformer :

Check to see if the peak starting current could cause:
— a trip on the high voltage side of the transformer,
— too large a voltage drop in the distribution system of the installation especially if the motor is a considerable distance from the power source.

- **If the installation allows a high peak**

The direct on line starter (squirrel cage motor) permits starting of all machines even at full load. However if the machine requires a slow and progressive start up the torque should be reduced, which means reducing the peak.

- **If the system installation will not allow a high peak**

Choose a starting method which allows the starting peak to be reduced taking into account the mechanical characteristics of the machine and such that the motor torque available at switch on is not less than 5/3 of the load torque. To do this, determine in which category of machine the load in question belongs and by comparison select the starting method.

2 - Determine the starting method

(if direct on line starting is impossible)

a) Machines with low torque which is practically constant during starting.

In this case the machines are started off load:
— Conventional machine tools: lathes, milling machines, drilling machines, presses, etc.
— Wood working machines: circular saws, shapers, planers, band saws, etc.
— Agricultural machines such as cream separators.
— Machines such as metal cutters, grinding wheels, centrifugal separators, etc.

Squirrel cage motor: star delta starter

Above a few hundred kW or when the voltage is high (500 V) the risk of high transient conditions makes it advisable to use an appropriate variant of star delta starting or another starting method.

b) Machines having a starting load torque of about half the load torque in normal running.

These are machines in which there is considerable starting friction such as:
— A tannery drum in which the friction of the skins creates an appreciable load torque.
— A machine or group of machines driven by belts where efficiency is low.

Squirrel cage motor: primary resistance starter or autotransformer starter.

If the peak starting current must be even further reduced, principally for machines with high power ratings.

Slipring motor: rotor starter.

c) Centrifugal machines.

In particular pumps and fans.

• Machines with medium power ratings (for example up to 55 kW).

Squirrel cage motor: star delta starter.

• High power machines (above 55 kW).

Squirrel cage motor: primary resistance starter or autotansformer starter (usually preferable especially in the case of high inertia drives).

Slipring motor: rotor starter.

d) Machines starting on full load.

These are machines which start under their normal working conditions e.g.
— Elevators or hoisting machinery.
— Belt and other conveyors.
— Printing machines. shears.
— Paper machines, mixers.
— Piston type compressors.
— Volume or piston pumps, etc.

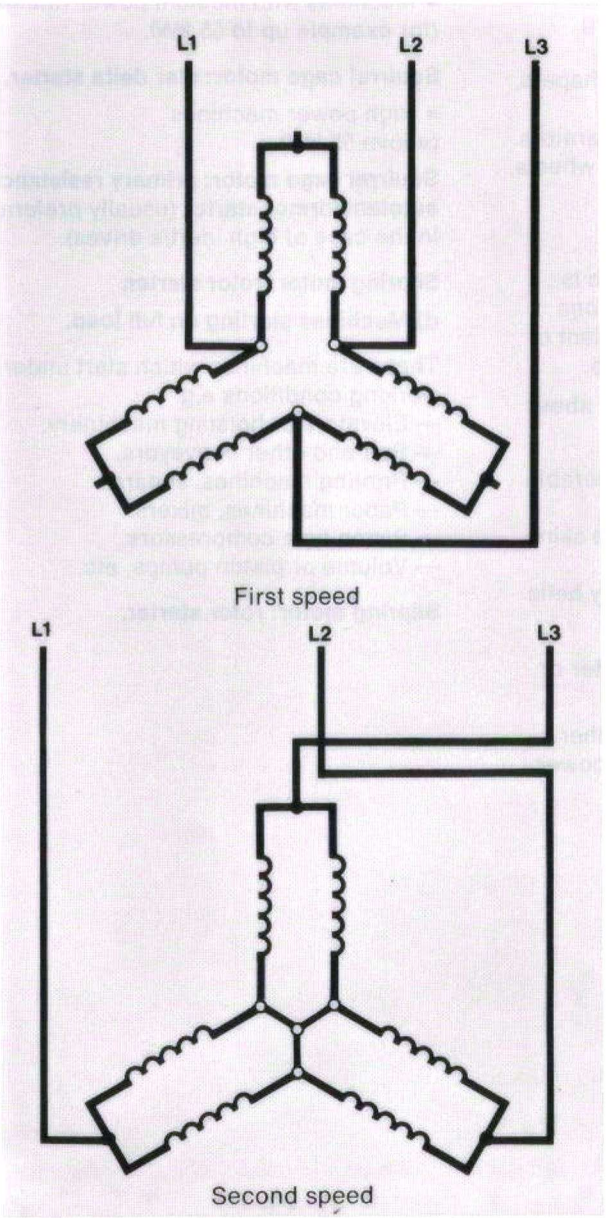
Slipring motor: rotor starter.

SPEED REGULATION OF INDUCTION MOTORS

As we have mentioned before, the speed of a squirrel cage motor is a function of the frequency of the supply and the number of poles. It is therefore possible to obtain a motor with two or more speeds by having winding combinations in the stator which correspond to the different numbers of poles.

Motors with pole changing

This type of motor offers speed ratios of 1 to 2 only (4 and 8 poles, 6 and 12 poles, etc.) and has six terminals.

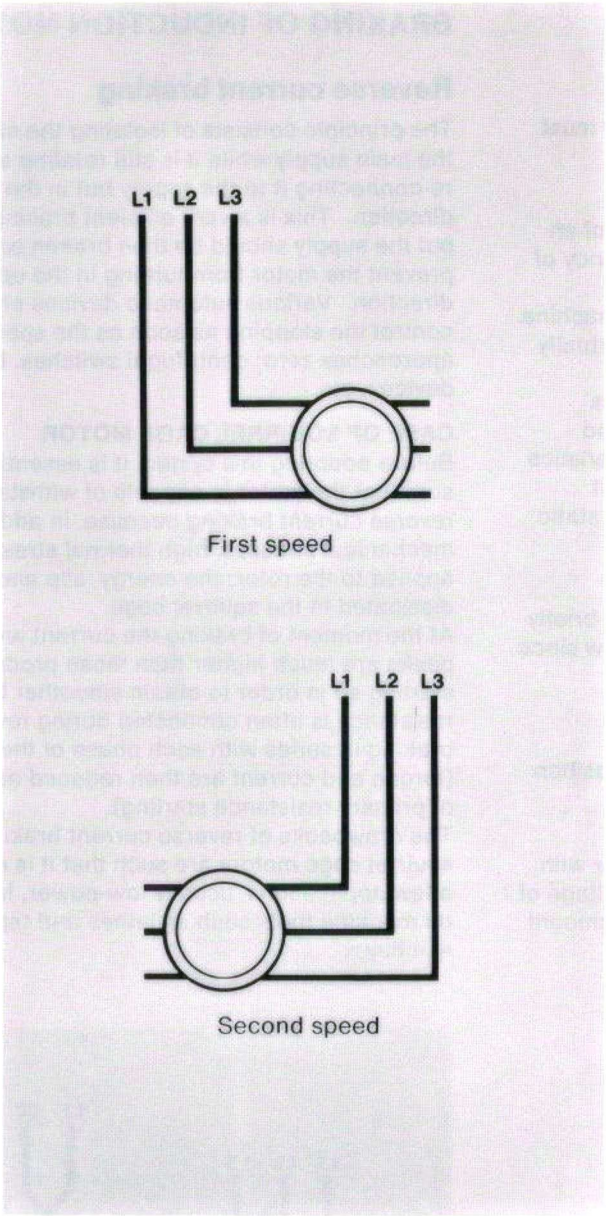


The motors can be of constant horsepower, constant torque or variable torque and horsepower.
For one of the speeds the main supply is connected to three terminals; for the second these terminals are connected together while the main supply is connected to the other three terminals.
Usually direct starting is used in high speed as well as in low speed and in some cases the starter automatically makes the transition to low speed before switching to high speed or before stopping.
Protection can be provided by one or two overload relays.
Generally speaking these motors have a low efficiency and power factor and when several motors of this type are to be operated together connecting them in parallel is not recommended. Even if these motors have the same power rating and are of identical construction varying currents may flow which can trip the overload relays.

Motors with separate stator windings

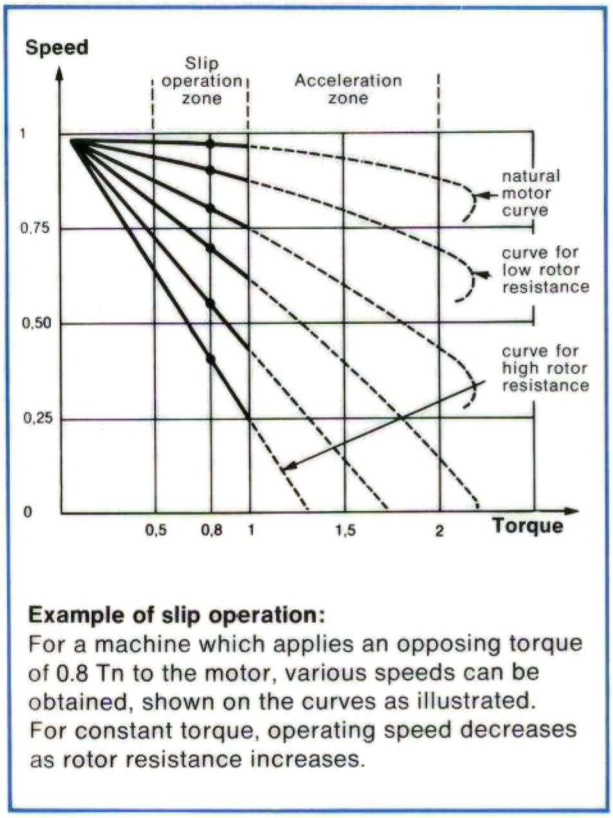
This type of motor, having two electrically independent stator windings, provides two speeds of any ratio. Since the low speed windings must be able to withstand the mechanical and electrical stresses resulting from operation of the motor at high speed, their electrical characteristics are often affected. Sometimes such a motor operating at low speed consumes a higher current than when operating on high speed.

Motors can also be produced with three or four speeds by connecting the poles to one or two of the stator windings. This configuration requires additional taps on the windings.



This simple method is often used although it presents two important drawbacks:

- During operation at reduced speed a large part of the power is consumed as a loss in the resistors.
- The speed obtained is not independant of the load, that is to say of the opposing torque applied by the machine to the motor shaft. For a given resistance the slip, i.e. the drop in speed with respect to the synchronous speed (at no-load), is proportional to the torque. The drop in speed obtained by a resistance could be 50% at full load and only 25% at half load, whereas the no load speed would remain unchanged.



Example of slip operation:
For a machine which applies an opposing torque of 0.8 Tn to the motor, various speeds can be obtained, shown on the curves as illustrated. For constant torque, operating speed decreases as rotor resistance increases.

Slipring motors

Slip speed regulation

The addition of a permanent resistance in the rotor circuit of a slipring motor reduces its speed, more resistance causing greater reduction in speed. These slip resistors can be shorted out in several steps either to obtain speed control in steps or acceleration until the motor is brought up to speed.

If an operator continuously monitors the machine he can, by changing the value of the resistance at will, set the speed in a certain zone for relatively high torques, but control is practically impossible for low torques. If he inserts a very high resistance to obtain a "low speed, low torque" point the slightest variation in torque changes the speed from zero to nearly 100% and the characteristic is too unstable.

Other speed regulation systems

STATIC SYSTEMS
These systems are now the most popular for most applications.

FREQUENCY CHANGING
We have seen above that the no load speed of an induction motor is proportional to the frequency of the supply.
To maintain constant torque the flux in the machine should not vary and the voltage should be virtually proportional to the frequency.
Slip remains constant and therefore becomes relatively greater for low speeds. This method permits low speeds with very stable characteristics to be obtained although it is costly because it requires a variable frequency generator or a static frequency converter.

ELECTROMECHANICAL SYSTEMS
Electromechanical speed regulating system, briefly described below, are in less frequent use now since the introduction of electronic variable speed systems.

AC commutator motors
Speed variation is obtained by varying the position of the brushes on the commutator.

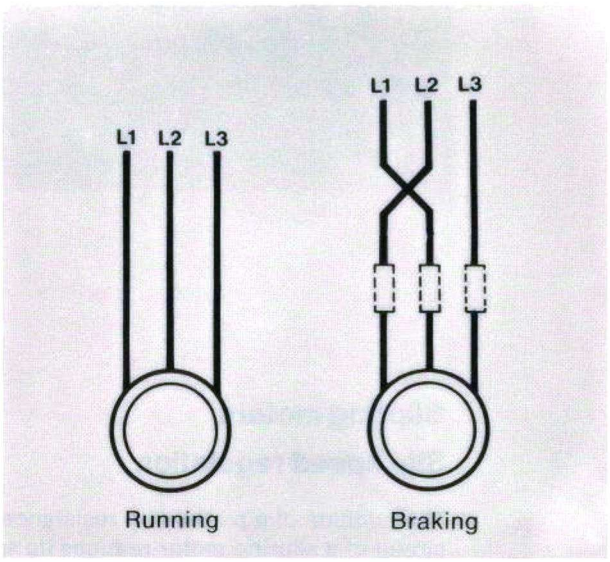
Voltage tapping
A system of rectifiers and an autotransformer with variable secondary voltage fixes the rotor voltage of the motor, and therefore its speed. A large amount of power is dissipated in the resistor.

BRAKING OF INDUCTION MOTORS

Reverse current braking

The principle consists of isolating the motor from the main supply while it is still rotating and re-connecting it to the supply but in the reverse direction. This is a very efficient braking method but the supply should be then broken early enough to prevent the motor from turning in the opposite direction. Various automatic devices are used to control the stopping as soon as the speed approaches zero: centrifugal switches, timing devices, etc.

CASE OF SQUIRREL CAGE MOTOR
Before adopting this system it is essential to make sure that the motor is capable of withstanding reverse current braking because, in addition to mechanical stresses, high thermal stresses are applied to the rotor; the energy, slip and kinetic, is dissipated in the squirrel cage.
At the moment of braking the current and torque peaks are much higher than those produced during starting so in order to obtain smoother braking a resistance is often connected during reverse current braking in series with each phase of the stator (torque and current are then reduced as in the case of primary resistance starting).
The drawbacks of reverse current braking for squirrel cage motors are such that it is used only in a few applications, usually low-power, for example on machine tools such as lathes and tapping machines.



Note - The resistors are not necessary if the motor and the load can withstand the effects of reverse current at full voltage.

CASE OF A SLIPRING MOTOR

In order to limit the current and torque peaks it is essential before connecting the stator of the motor for reverse current, to reinsert the rotor resistances used for starting and often even to add an extra "braking" section.

The braking torque can be easily adjusted to the desired value by selecting a suitable rotor resistance.

At the moment of reversal the rotor voltage is almost twice the rotor voltage at standstill which sometimes requires special winding insulation.

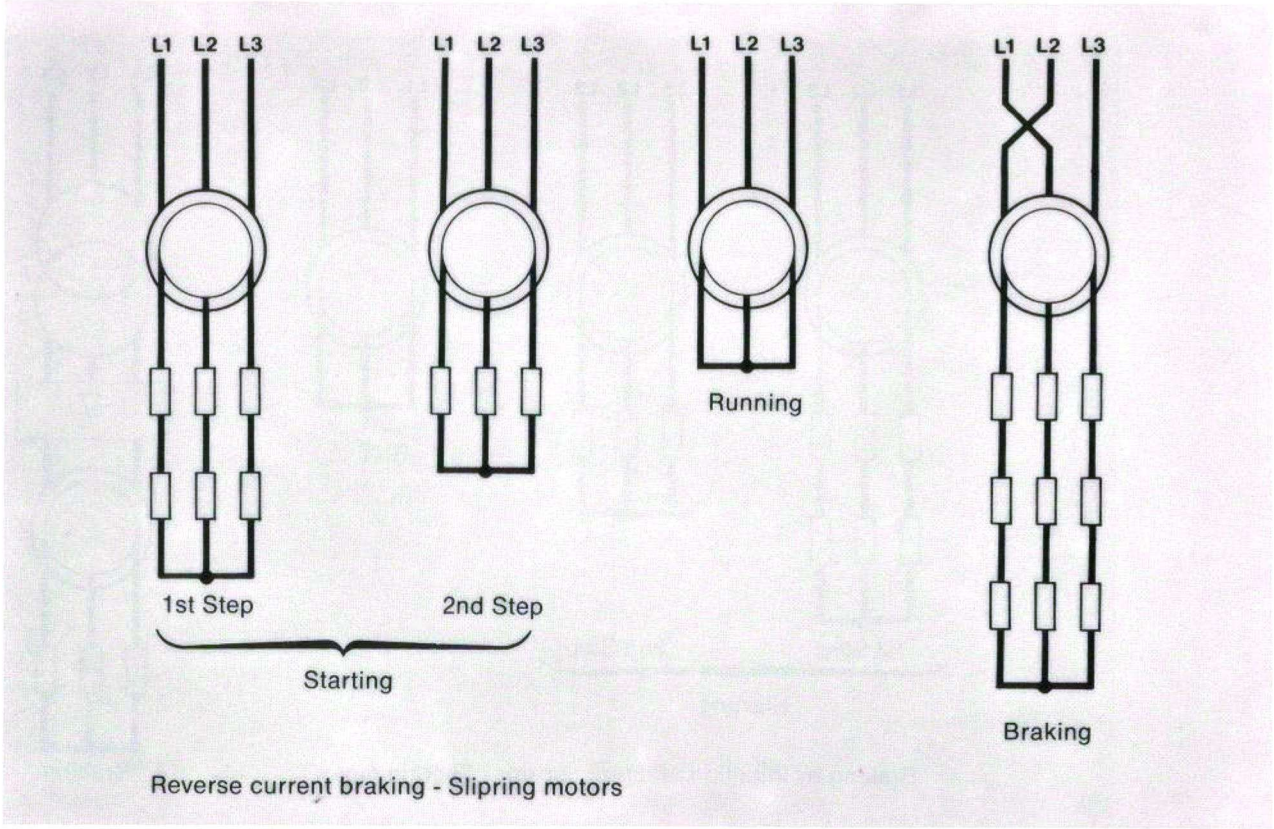
Much energy is dissipated in the resistors: slip energy taken from the line and kinetic energy from the masses in motion. When standstill is approached stopping can be automatically controlled by the devices mentioned above or by the use of voltage or current relays in the rotor circuit.

The characteristic is very unstable with large variations in speed for small variations in torque.

Braking by injection of direct current

Like reverse current braking this system is used mainly with slipring motors but the principles for its use with squirrel cage motors remain the same. With respect to the reverse current system, the cost of the d.c. source is balanced by the lower cost of the resistors.

This method consists of applying direct current to the stator after it has been disconnected from the supply. To produce suitable braking the current should be approximately 1.3 times the rated current and the actual value is determined solely by the resistance of the stator windings so the voltage to the d.c. source is low (for example 20 volts). This source usually contains rectifiers and they should be able to withstand the transient over-voltages produced by the windings which have just been disconnected from the a.c. supply. The movement of the rotor constitutes a slip with respect to a field which is fixed whereas in the reverse current system

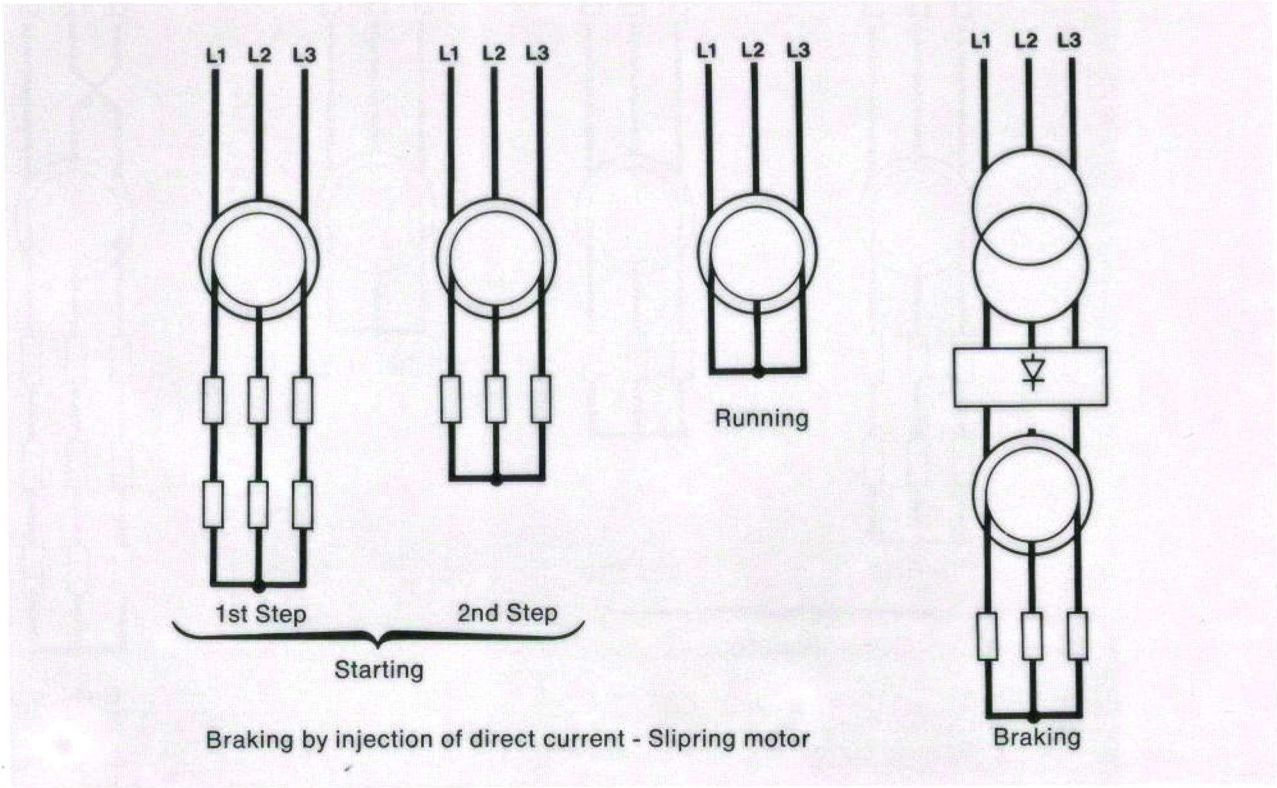


Reverse current braking - Slipring motors

this field rotates in the reverse direction. A slipring motor, for example, behaves like a synchronous generator delivering into the rotor resistors.
The characteristics of d.c. injection braking systems present, with respect to those of a reverse current systems, important differences:
— the energy dissipated in the rotor resistors or in the squirrel cage is much lower being only the equivalent of the mechanical energy conveyed by the moving masses and the only energy taken from the main supply is the stator "excitation";
— the motor does not restart in the reverse direction;
— if the load is overhauling, the system provides continuous braking which holds this load down to a low speed and the characteristic is much more stable than with reverse current braking.
In the case of the slipring motor the torque-speed characteristics depend upon the choice of resistances.
In the case of the squirrel cage motor, braking torque can be easily varied by adjusting the d.c. excitation.
In order to prevent unnecessary heating the use of a device is recommended to cut off the stator current once the braking is completed.

Braking by super synchronous operation

This is the case in which the motor is driven by its load above its synchronous speed. It then acts like an induction generator and develops a braking torque; except for losses the energy is recovered by the line supply.
With a hoist motor the lowering of the load at rated speed corresponds to this type of operation: the braking torque exactly balances the torque due to the load providing not a decrease in speed but constant speed operation.
When a slipring motor is involved it is essential to short out all the rotor resistance otherwise the motor would be driven far beyond its rated speed with the accompanying mechanical risks.
This system is ideal for holding back an overhauling load:
— the speed is stable, almost independent of the driving torque;
— the energy is recovered and returned to the line supply.
Of course it corresponds to a single speed only, that is to say approximately the rated speed but it is also used with multiple speed motors when changing from high to low speed.



Braking by injection of direct current - Slipring motor

Other braking systems

ELECTRONIC SYSTEMS

Many of these systems are capable of controlling the speed of a machine under load and also of providing braking with specific characteristics.

MISCELLANEOUS SYSTEMS FOR INDUCTION MOTORS

A few methods less often used are mentioned below for the record:

Direct current braking with self excitation

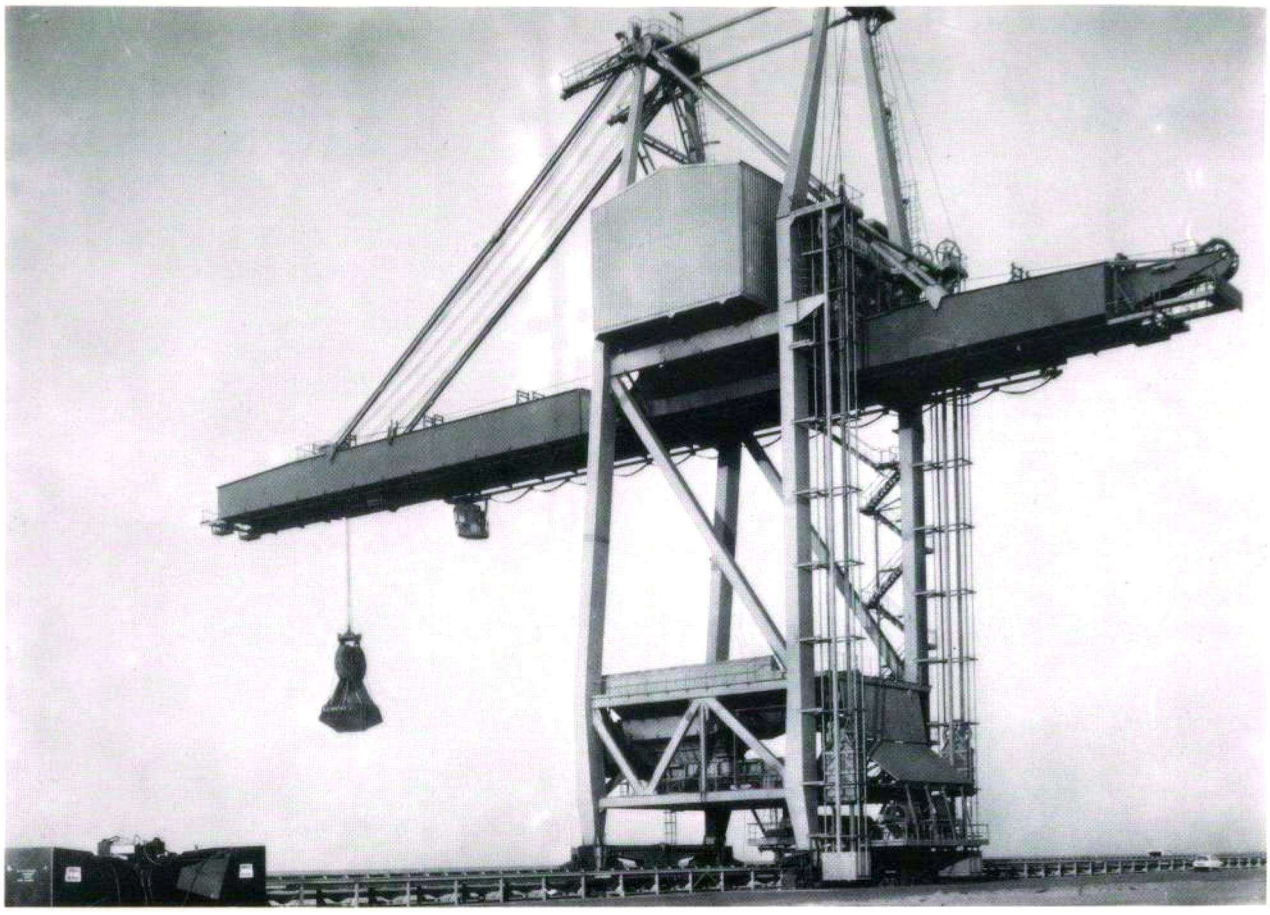
The motor itself is the source of direct current. The excitation current depends upon the torque developed and for this reason the torque-speed characteristics are much more stable.

Single phase braking

The motor, supplied by two phases of the main supply, operates with a no load speed lower than the normal synchronous speed. This system is accompanied by imbalance and losses.

BRAKING SYSTEMS USING AUXILIARY DEVICES

This subject does not lie within the scope of this publication but one common method can be cited which consists of adding an eddy current brake to an induction motor. The mechanical energy is dissipated in heat but braking can be easily controlled by adjustment of the eddy current device.



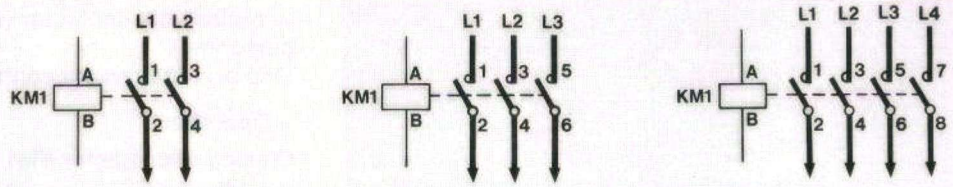
50-tonne "CAILLARD" gantry crane installed at the port of Dunkirk.

basic schematics

CONTROL OF A SINGLE CONTACTOR

POWER CIRCUIT

The contactor contains a certain number of poles; simply insert each of them in the cables supplying the load.



To direct current or single phase load

To three phase load

To multiphase load

CONTROL CIRCUIT

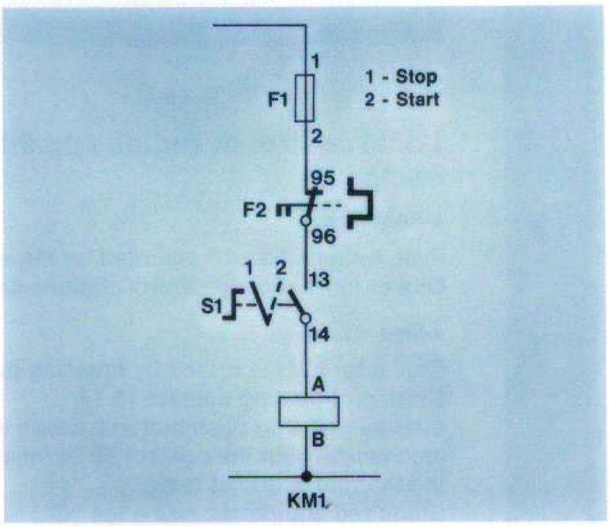
Manual control by switch

- **Features**

Switch is maintained in the closed position by a latching device.
When the supply is interrupted contactor KM1 opens and the motor which drives the machine stops.
When the line supply reappears, since the switch contact is closed, the contactor recloses and the machine starts again without the operator being warned, safety for personnel is not entirely ensured.

- **Operation**

Closing of contactor KM1 by contact (13-14) of switch S1.
(Required equipment, see page 103.)



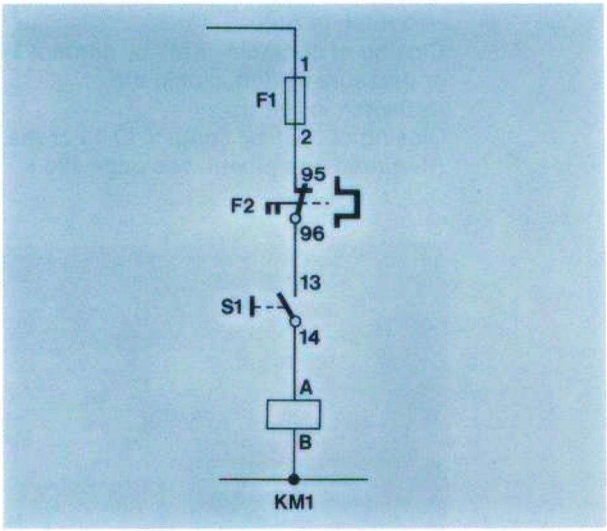
Manual control by spring return push button

- **Features**

Spring return push button.
The contactor coil is energized only while button is depressed.

- **Operation**

Closing of contactor KM1 by contact (13-14) of push button S1.
(Required equipment, see page 103.)



Automatic control

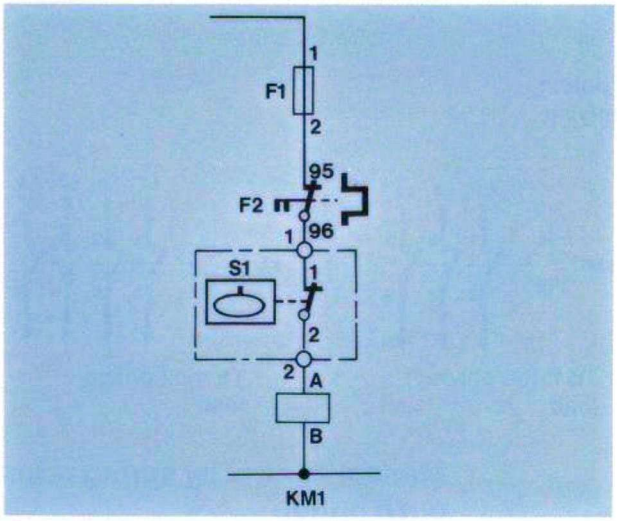
- **Features**

Operation without surveillance.
Contact of protection relay F2 is fitted with a latching device.

- **Operation**

Closing of contactor KM1 by contact 1-2 actuated by a float or pressure switch, timer, etc.
(Required equipment, see page 103.)

control of a single contactor



Remote control by two spring return buttons

- **Features**

When the supply is interrupted the contactor opens but push button S2 must be pressed again in order to reclose the contactor (complete safety for personnel).
One or more remote control stations can be added.

- **Operation**

Closing of contactor KM1 by contact 13-14 of push button S2.
Hold in by contact 13-14 of KM1.
Stop by contact 11-12 of push button S1.
(Required equipment, see page 103.)

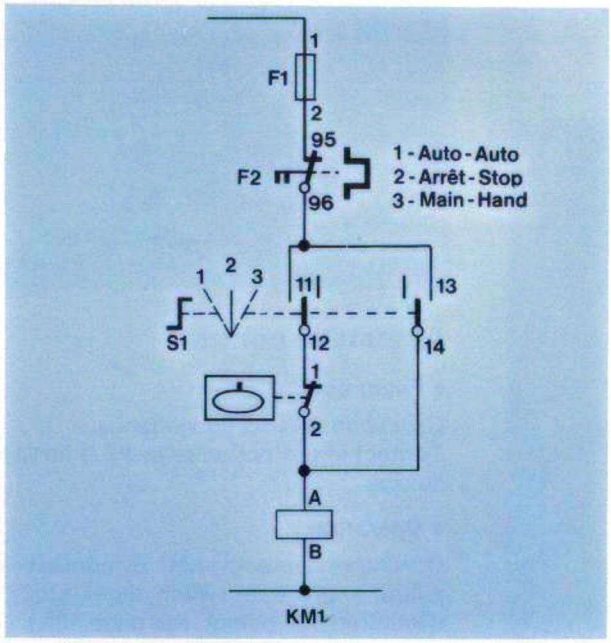
Automatic or manual control by "auto-off-hand" switch

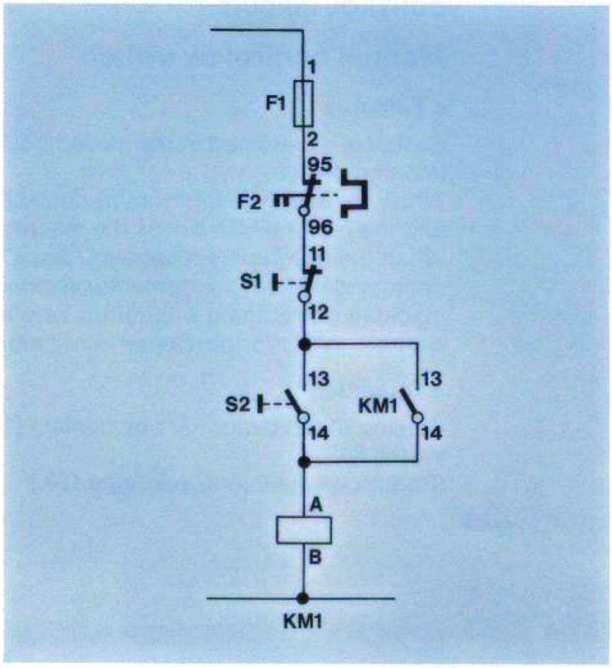
- **Features**

In Hand position contact 1-2 is shorted by that of the selector switch and the installation requires monitoring by the operator.

- **Operation**

— Switch in Auto:
Closing of contactor KM1 by contact 1-2 of float or pressure switch, clock, etc.
— Switch in Hand:
Closing of KM1 by contact 13-14 of the switch.
(Required equipment, see page 103.)





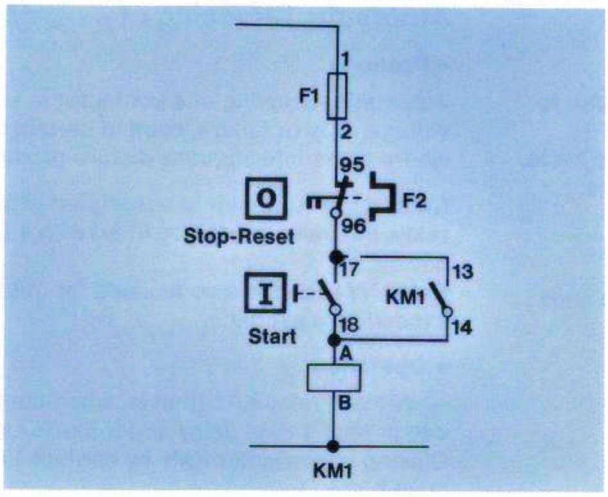
Local control by buttons on the starter enclosure

- **Features**

Push buttons 1 and 0 mounted on the enclosure.
One or more remote control stations can be added.

- **Operation**

Contactor KM1 is closed by pressing push button 1.
Closing of holding contact 13-14.
Stop by pressing push button 0 which acts mechanically on the contact 95-96 incorporated in the thermal overload relay.
(Required equipment, see page 103.)



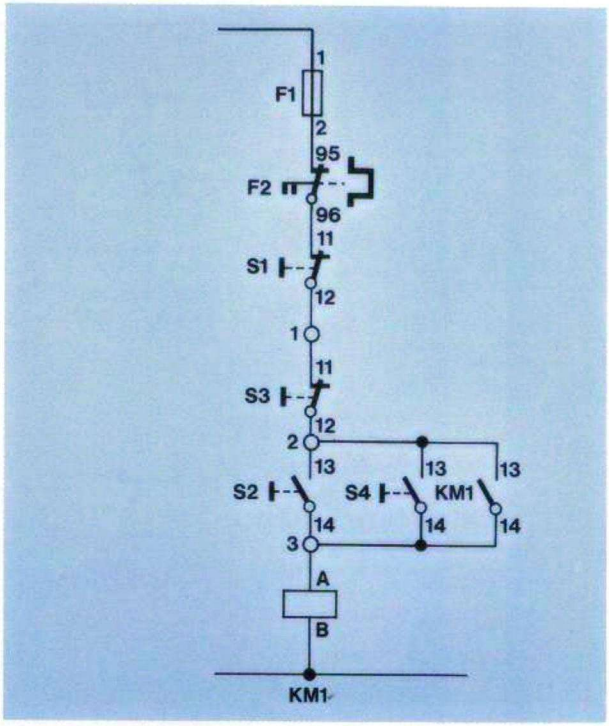
Remote control by several spring return push buttons

- **Features**

Possibility of remote control from several points.

- **Operation**

Closing of contactor KM1 by any of the start buttons S2-S4 connected in parallel. Hold in by contact 13-14.
Stop by any of the stop buttons S1-S3 connected in series.
(Required equipment, see page 103.)



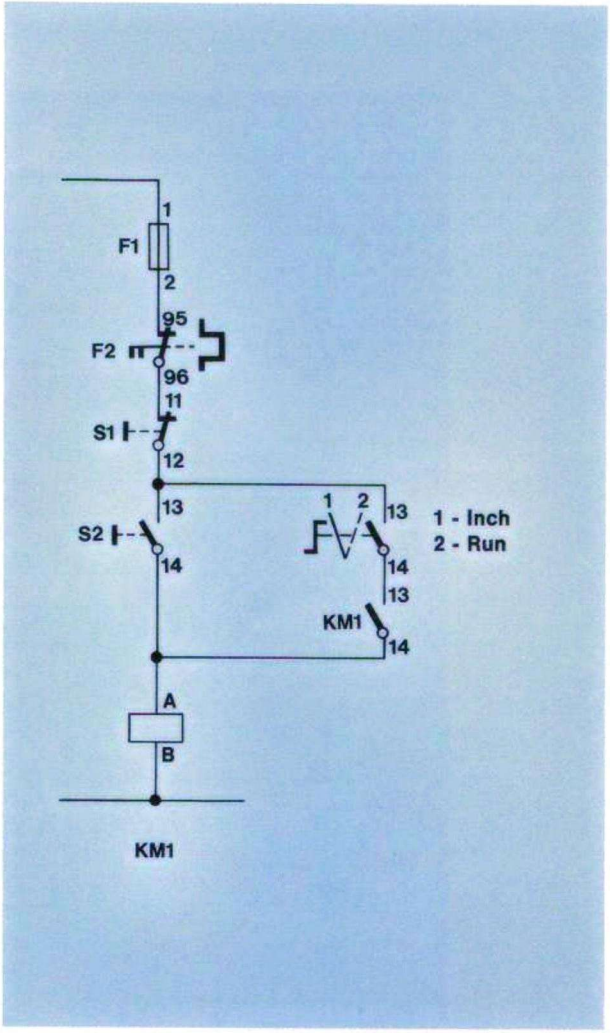
"Run-Inch" remote control

- **Features**

Possibility of inching during the setting up of a machine (machine tool, printing machine) or for positioning of a workpiece.

- **Operation**

— Switch in "Run":
Contact 13-14 of switch closed.
Closing of contactor KM1 by contact 13-14 of the start push button S2.
Hold in by 13-14 of KM1.
Stop by contact 11-12 of push button S1.
— Switch in "Inch":
Contact 13-14 of switch open.
Closing of KM1 by contact 13-14 of start push button S2, but opening of KM1 as soon as S2 is released.
(Required equipment, see page 103.)



Interlocking of start push button

• **Features**

Possibility of relating the opening of a contactor to the position of a machine or mechanical part (circular cam, etc.) at the end of an automatic cycle, before allowing the start of the following cycle.

• **Operation**

— Contact 11-12 of S3 closed:
Closing of contactor KM1 by contact 13-14 of start push button S2.
Hold in by 13-14 of KM1.
Opening of 11-12 of S3 has no effect.
Stop by contact 11-12 of push button S1.
— Contact 11-12 of S3 open:
Pushing start button S2 has no effect.
(Required equipment, see page 103.)

Automatic reclosing of a contactor

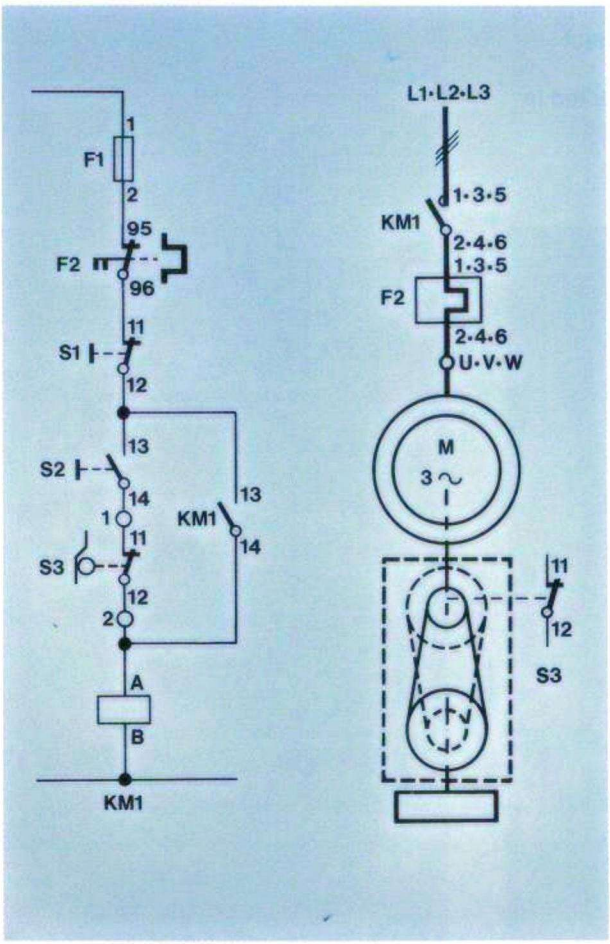
• **Features**

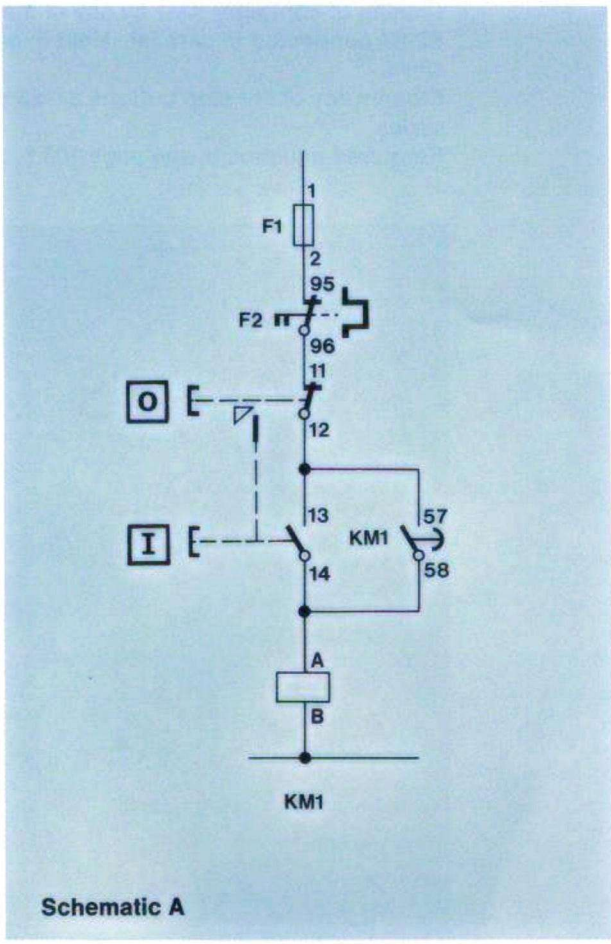
Automatic reclosing of a contactor in case of mains voltage drop or failure, used in certain industries where these interruptions disturb production.

Note: If the contactor is associated with a protection relay, this relay should be fitted with a latching device.
Relay NY1-R5 can also be used for interruptions not exceeding 4 seconds.

• **Operation**

— Without relay KA1 (that is, when contactor KM1 can accept a time delay adder block - schematic A).
Closing of contactor KM1 by contact 13-14 of push button I.





Schematic A

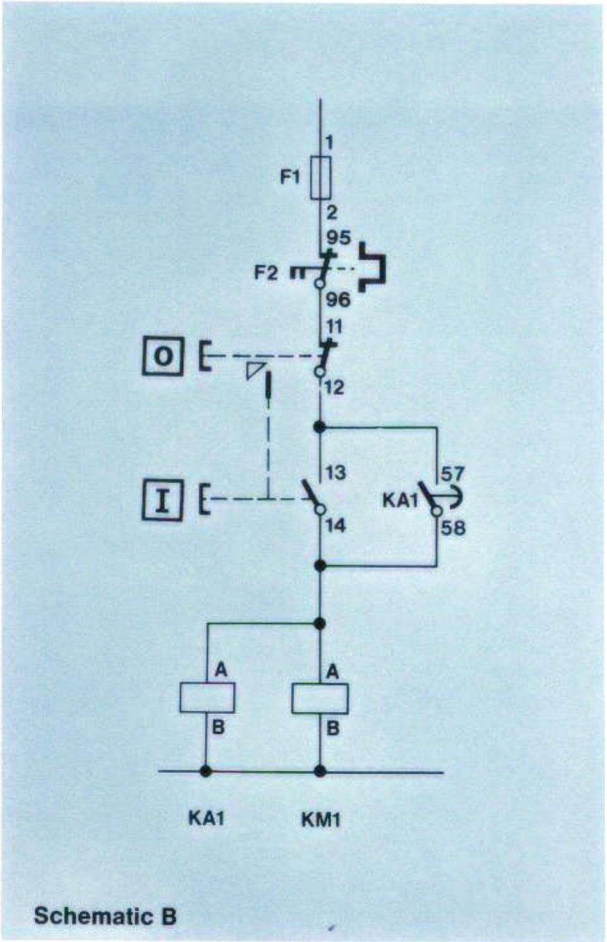
Hold in of KM1 by 57-58.
When a large drop in voltage or a voltage failure occurs, KM1 opens.
If the interruption is less than the delay time of contact 57-58 (maximum of 3 minutes), KM1 closes as soon as voltage returns. If the interruption is longer, KM1 remains open.
Immediate stop by contact 11-12 of latching push button 0.

— With control relay KA1 (that is when contactor KM1 cannot accept a time delay adder block - schematic B).
Same principle, KM1 and KA1 closing and opening simultaneously.

Note: Use a latching push button released by a spring return push button i.e., XB2-MH5, etc.

REQUIRED EQUIPMENT

All equipment for these basic schematics can be obtained from:
- Our range of contactors:
LC1; CN or **CV** as well as special contactors.
- Our preassembled units:
LC4-D.
- Our enclosed equipment and their variations:
LE1-D; LE4-D; NC1; ND1 or **NB1,** etc.
- Our range of pilot devices:
manual - **XAB; XAF; XAG; XBF** or **XB2-M,** etc.
automatic: **XL** or **XM,** etc.
- Our equipment accessories.



Schematic B

Control by switches

(schematic A)

• Features

Possibility of reversing the direction of a motor.
Starting and stopping are controlled by the operator.
Mechanical and electrical interlocks between the two contactors.

• Operation

— Contact 11-12 of switch closed.
Closing of contactor KM1 if KM2 is open.
Opening of contact 31-32 of KM1 (electrical interlock with KM2).
Stop by action of switch S1.
— Contact 13-14 of switch closed.
Closing of contactor KM2 if KM1 is open.
Opening of contact 31-32 of KM2 (electrical interlock with RM1).
Stop by action of switch S1.

• Required equipment

See page 105.

Control by limit switches

(schematic B)

• Features

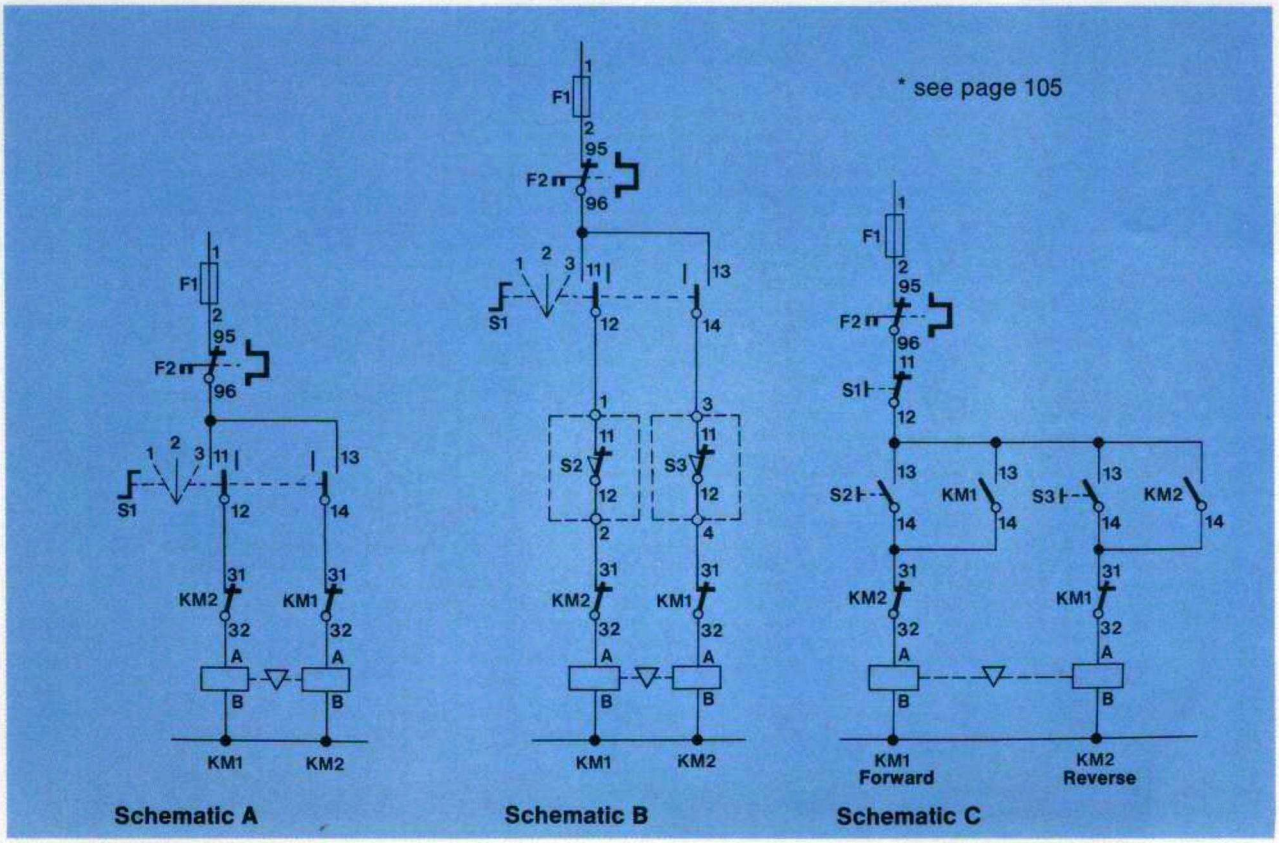
The same as before but with automatic stop at the end of travel.

• Operation

— Contact 11-12 of switch closed.
Closing of contactor KM1 if limit switch S2 closed and contactor KM2 open.
Opening of contact 31-32 of KM1 (electrical interlock with KM2).
Stop by action of switch S1 or by limit switch S2.
— Contact 13-14 of switch closed.
Closing of contactor KM2 if limit switch S3 is closed and contactor KM1 open.
Opening of contact 31-32 of KM2 (electrical interlock with kM1).
Stop by action of switch S1 or by limit switch S3.

• Required equipment

See page 105.



control of two contactors

Control by spring return buttons

(schematic C)

• Features

Possibility of reversing the direction of a motor.
Starting and stopping are controlled by the operator.
Mechanical and electrical interlocking between the two contactors.

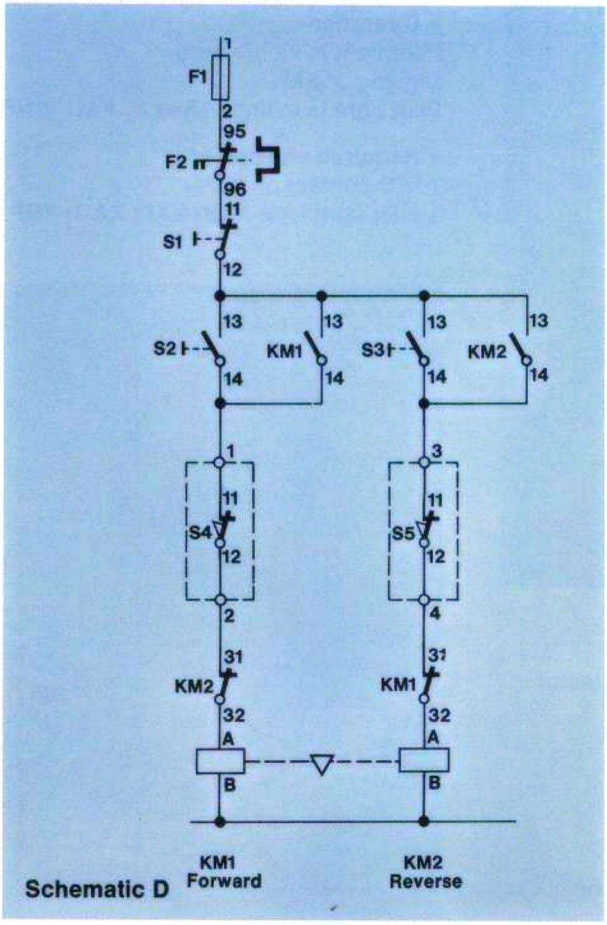
• Operation

Forward:

Press push button S2.
Closing of contactor KM1 if KM2 is open.
Hold in of KM1 (13-14).
Opening of contact 31-32 of KM1 (electrical interlock with KM2).
Stop by push button S1.

Reverse:

Press push button S3.
Closing of contactor KM2 if KM1 is open.
Hold in of KM2 (13-14).
Opening of contact 31-32 of KM2 (electrical interlock with KM1).
Stop by push button S1.



Schematic D

Control by spring return buttons and limit switches

(schematic D)

• Features

The same as before but with automatic stop at the end of travel.

• Operation

Forward:

Press push button S2.
Closing of contactor KM1 if limit switch S4 is closed and contactor KM2 open.
Hold in of KM1 (13-14).
Opening of contact 31-32 of KM1 (electrical interlock with KM2).
Stop by push button S1 or by limit switch S4.

Reverse:

Press push button S3.
Closing of contactor KM2 if limit switch S5 is closed and contactor KM1 open.
Hold in of KM2 (13-14).
Opening of contact 31-32 of KM2 (electrical interlock with KM1).
Stop by push button S1 or by limit switch S5.

REQUIRED EQUIPMENT

All equipment for these basic schematics can be obtained from:
• Our preassembled units:
LC2-D or **NC2,** etc.
• Our enclosed equipment and their variations:
LE2-D; NC2 or **ND2,** etc.
• Our range of pilot devices:
manual: **XAB; XAF; XAG; XBF** or **XB2-M,** etc.
automatic: **XCK; XC1; XC2; XCE** or **XF1** and **X** Series detectors, etc.
• Our equipment accessories.

*** As explained in the chapter "Standardisation of Electrical Schematics":**
• the second digit of the terminal reference of an instantaneous make (N/O) contact is 3-4 whereas that of an instantaneous break (N/C) contact is 1-2;
• the first digit indicates the physical position of each contact on the component.
Consequently the reference numbers shown on these schematics can be changed according to the composition of the equipment.

"Power on" indication

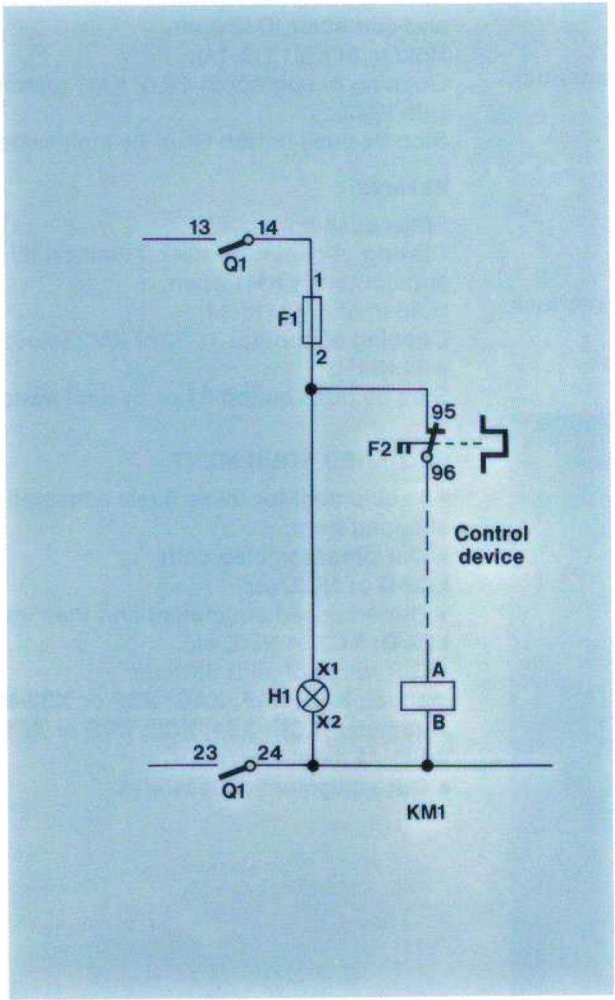
A pilot light indicates that the supply is connected to the installation. The power is switched on generally by means of an isolator placed on the supply side.

- **Operation**

Isolator Q1 is closed manually.
The pilot light is energized by Q1 (13-14 and 23-24).

- **Required equipment**

1 pilot light type **XAB; XAF; XAG; XBF; XB2; XV1,** etc.



"Start" signalling

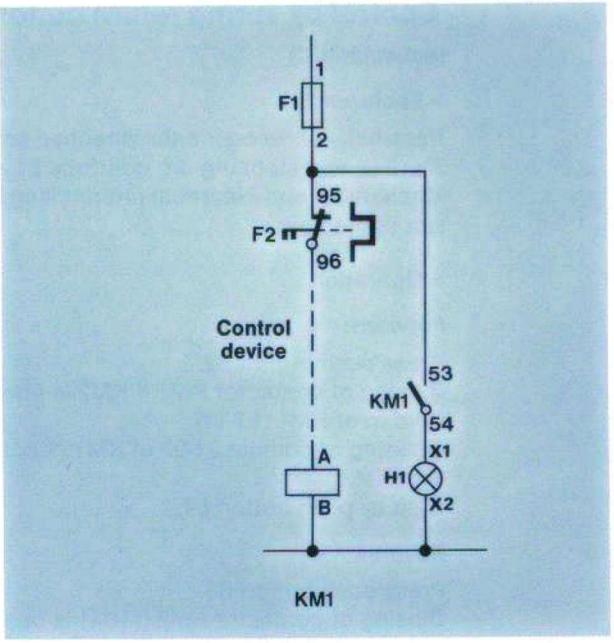
The pilot light indicates the closing of a contactor.

- **Operation**

Closing of KM1.
Pilot light is illuminated by KM1 (53-54).

- **Required equipment**

1 N/O contact on KM1.
1 pilot light type **XAB; XAF; XAG; XBF; XB2** or **XV1,** etc.



"Stop" signalling

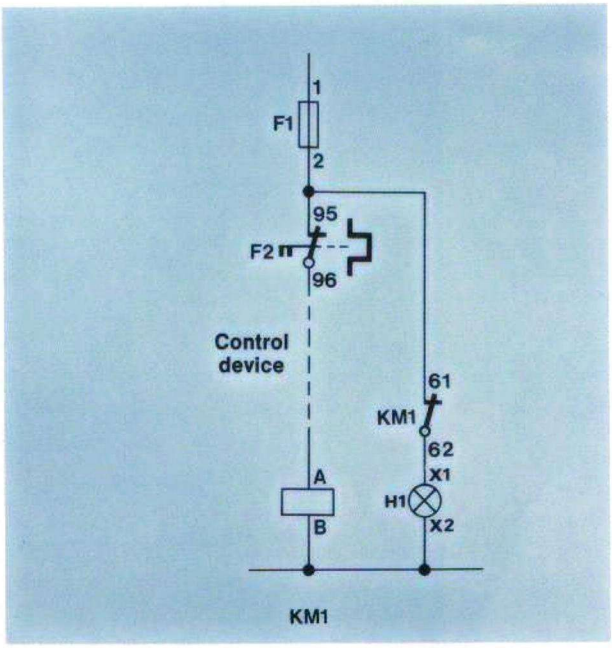
The opening of the contactor is indicated.

- **Operation**

Pilot light is illuminated.
Closing of KM1.
Pilot light is extinguished by KM1 (61-62).

- **Required equipment**

1 N/C contact on KM1.
1 pilot light type **XAB; XAF; XAG; XBF** or **XB2,** etc.

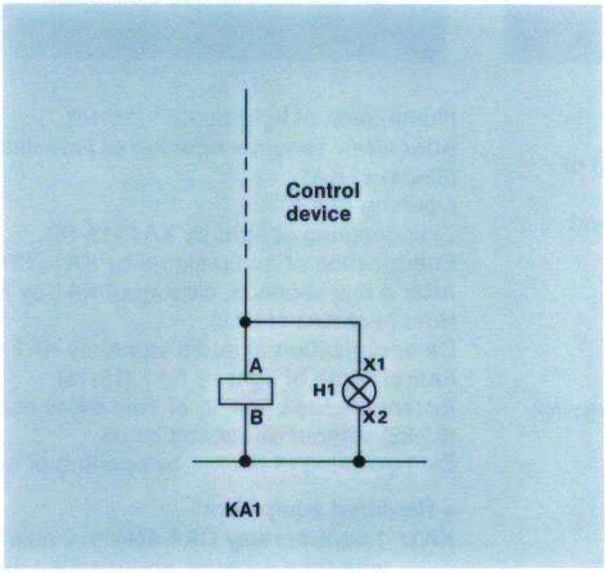


Local signalling at the load terminals

The pilot light is connected to the terminals of the load and signals its energization.
This device saves the use of a contact but if the load is inductive the peak voltage which occurs when the circuit is broken may damage the bulb. A transformer operated pilot light overcomes this problem.

• **Operation**
Simultaneous energization of load and pilot light.

• **Required equipment**
1 pilot light type **XAB; XAF; XAG; XBF; XB2; XV1,** etc.: may be with fitted transformer depending upon the application.

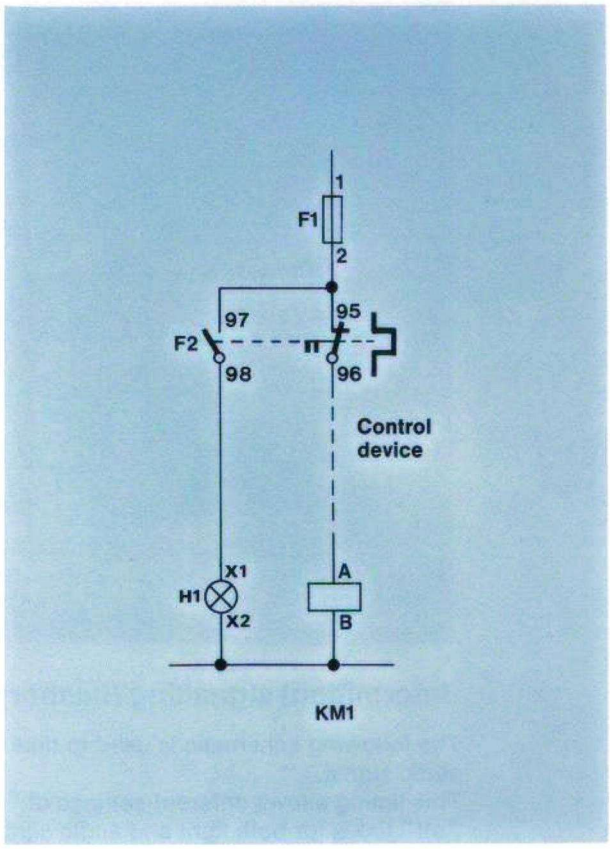


Fault signalling

This signal indicates the tripping of the load protection relay. The contact which controls the pilot light is incorporated in the protection relay.

• **Operation**
KM1 closed.
Overload occurs.
Tripping of F2.
Opening of KM1 by F2 (95-96).
Pilot light supplied by F2 (97-98).

• **Required equipment**
1 N/O contact on F2 (supplied on **LR1-D** or added to **RA1** and **RMT-D).**
1 pilot light type **XAB; XAF; XAG; XBF; XB2; XV1,** etc.

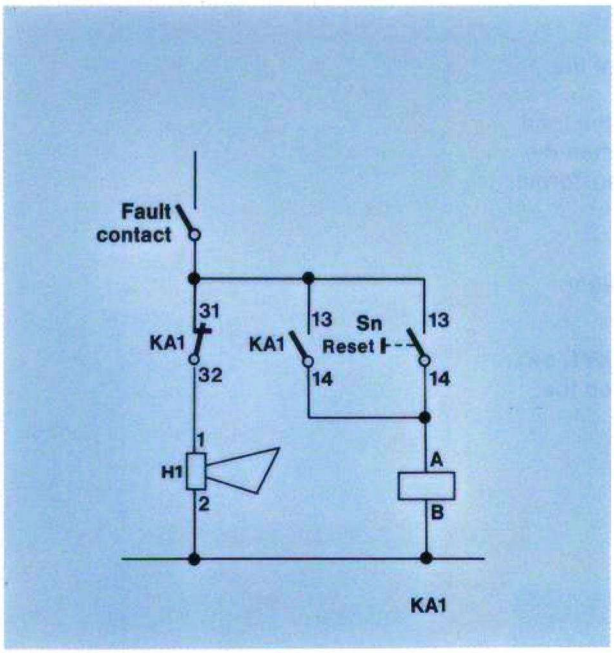


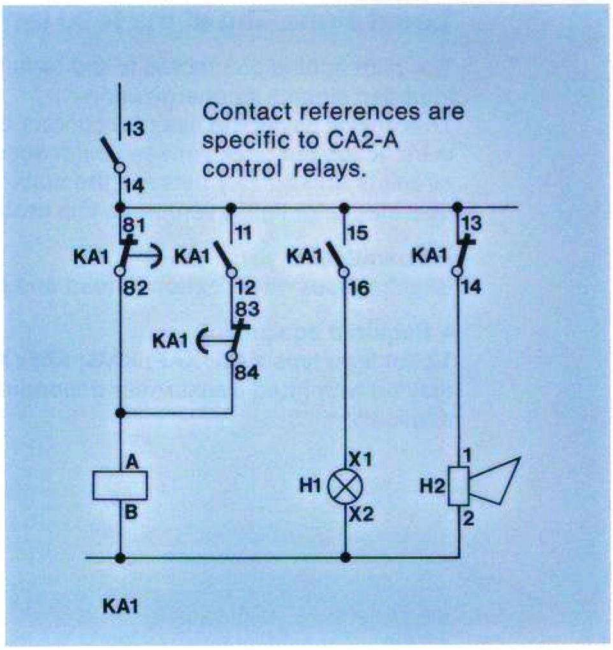
Audio warning with reset

The fault contact actuates an audio warning device which remains energized so long as the "reset" push button has not been operated. This circuit can also be used for a centralized calling system with several stations in which case the "fault" contact is replaced by one or more "call" push buttons.

• **Operation**
Closing of fault contact.
Energization of audio warning device (horn) H1.
Press button Sn.
Closing of KA1 by Sn (13-14).
De-energization of audio warning device by KA1 (31-32).
Hold in of KA1 (13-14).
Opening of KA1 by fault contact when the fault has been corrected.

• **Required equipment**
H1: 1 audio warning device.
KA1: 1 control relay (N/C + N/O)
CA2-AN; CA2-DN; CA2-FN
1 fault contact (protective device, control relay or call button).
Sn: 1 "reset" push button
XAB; XAF; XAG; XBF or **XB2,** etc.





Intermittent signalling (flasher)

The following schematic is used to time a light or audio signal.
This timing allows different settings of "on" and "off" times for both light and audio signals.

- **Operation**

Closing of contact 13-14.
Closing of KA1.
Hold in of KA1 (11-12).
Instantaneous opening of time delay contact (81-82) of KA1 with no effect.
Illumination of light by KA1 (15-16).
After a few seconds opening of time delay contact (83-84) of KA1.
Opening of KA1.
Extinguishing of light by KA1 (15-16).
Energization of audio signal by KA1 (13-14).
After a few seconds, closing of KA1 by KA1 (81-82).
Hold in of KA1 (11-12).
De-energization of audio signal by KA1 (13-14).
Energization of light by KA1 (15-16).
Instantaneous opening of time delay contact of KA1 (81-82) without effect and so on.
Extinguishing of flasher by opening of contact (13-14).

- **Required equipment**

KA1: 1 control relay **CA2-AN4** + 2 auxiliary blocks with time delay on energization and de-energization **CA2-AS-22** or **AS-24,** depending on the required delay times.

Protection by thermal overload relay

Protection against small and sustained overloads (refer to page 26).

- **Power circuit connection**

— On three phase alternating current: connect one element in each line.
— Single phase and direct current: connect one element in one of the power supply lines and connect the other two in series in the other line.

- **Control circuit operation**

KM1 closed.
Overload.
Tripping of F2.
Opening of KM1 by F2 (95-96).
Reset by push button of F2.

- **Required equipment**

F2: 1 thermal differential relay **RA1** or **LR1-D** or non-differential relay **RB1** or **LR3-D,** etc.

Protection by thermal magnetic relay

Protection against small and sustained overloads and high overcurrents.
(Refer to page 29.)

- **Power circuit connection**

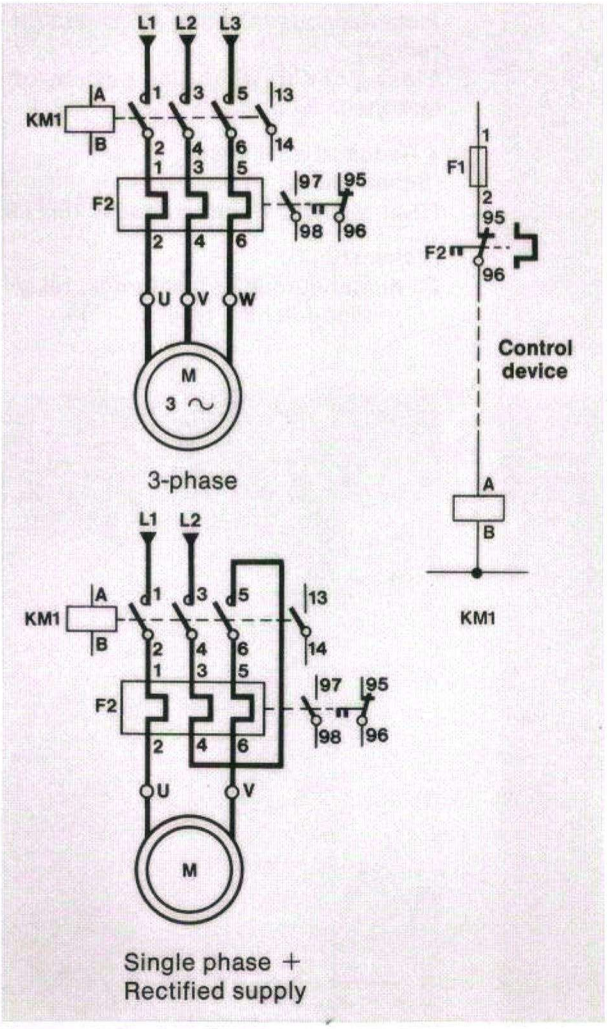
— On alternating current: connect a thermal magnetic element in each line
— On direct current: connect a magnetic element in one of the lines and a thermal element in the other.

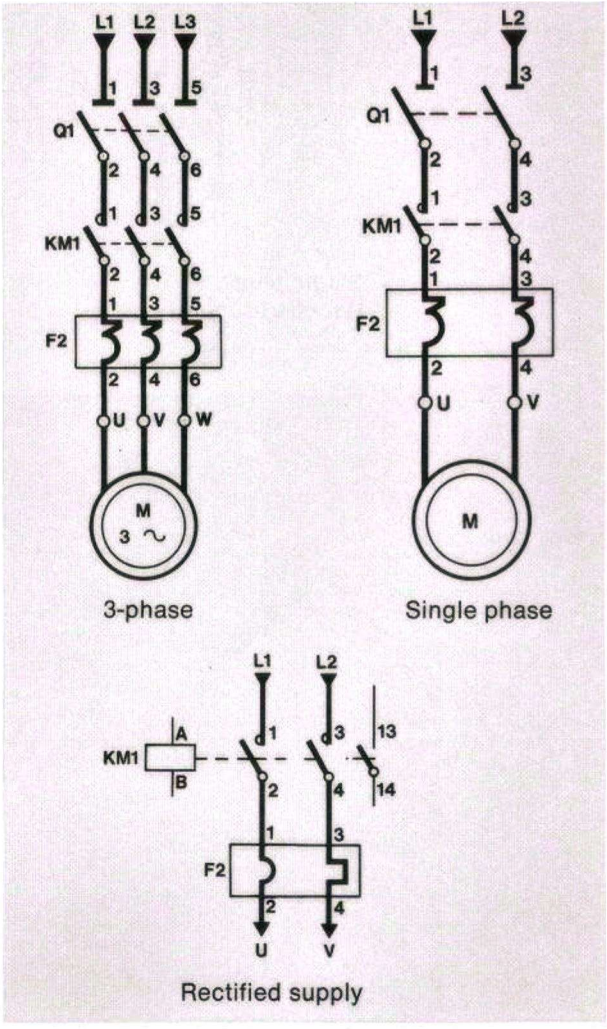
- **Control circuit operation**

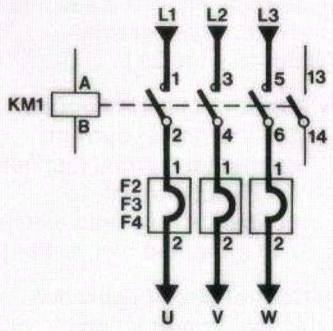
Identical to protection by thermal overload relay.

- **Required equipment**

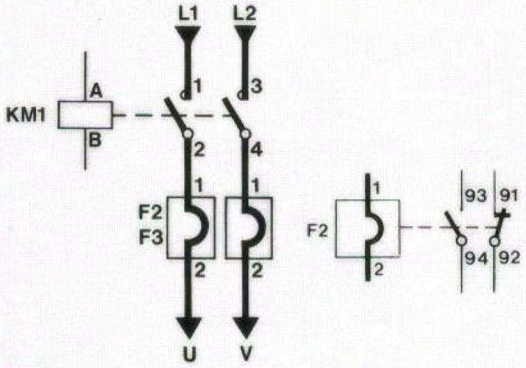
F2: 1 thermal magnetic overload relay **RMT-D** for alternating current or **RME-TL** for direct current.







3-phase



Single phase +
Rectified supply

Protection by electromagnetic overcurrent relay

Protection of installations subjected to frequent and high current peaks.
(Refer to page 31.)

- **Power circuit connection**

Connect an electromagnetic relay in each line.

- **Control circuit operation**

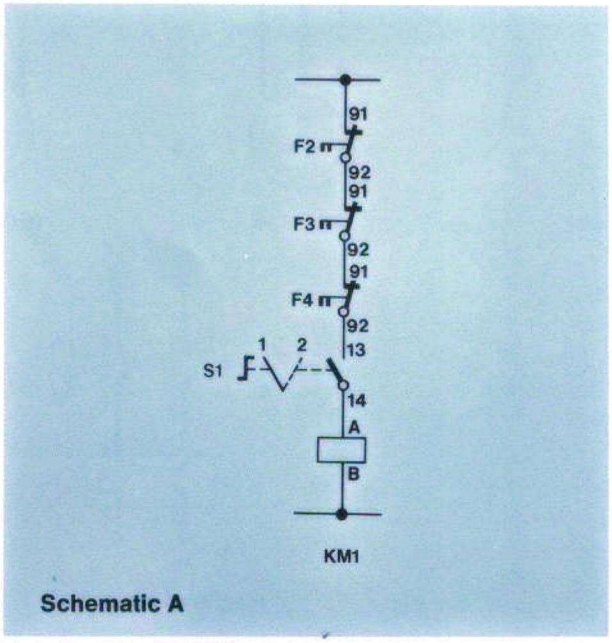
Schematic A:
KM1 closed.
High overcurrent.
Tripping of F2, F3 or F4.
Opening of KM1 by F2, F3 or F4 (91-92).
Resetting by the "reset" push button of the tripped relay(s).
If switch S1 is closed immediate closing of KM1.

Schematic B:
KM1 closed.
High overcurrent.
Tripping of F2, F3 or F4.
Opening of KM1 by F1, F2 or F3 (91-92).
Instantaneous resetting of contact (91-92) of tripped relay(s).
Closing of KM1 when start push button S2 is operated.

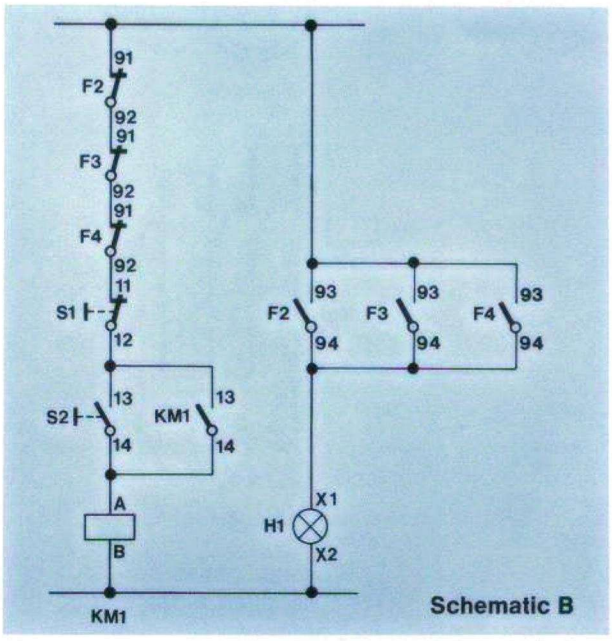
- **Required equipment**

(Schematic A)
F2-n: latching electromagnetic relay **RM1-XA.**

(Schematic B)
F2-n: standard electromagnetic relay **RM1-XA** (non-latching type).



Schematic A

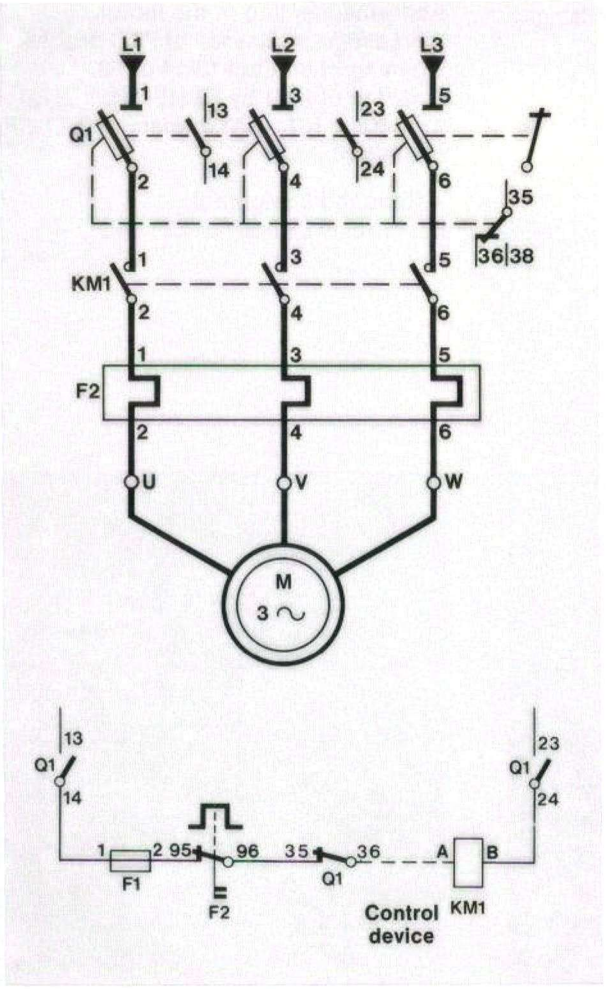


Schematic B

Protection against single phase condition

Protection of a motor against the single-phase condition after blowing of a striker fuse placed on the supply side.
Response time is less than that of a thermal overload relay equipped with a differential device.
(Refer to page 27.)

- **Power circuit connection**



- **Control circuit operation**

KM1 closed.
Blowing of a fuse equipped with a striker.
Control device actuated by the striker.
Opening of contact (35-36).
Opening of KM1.

- **Required equipment**

Q1: 1 isolator fitted with striker fuse mechanism **DK1.**

F2: 1 thermal differential relay **RA1** or **LR1-D.**

Protection by bimetal thermal probe (with trip on thermal overload relay)

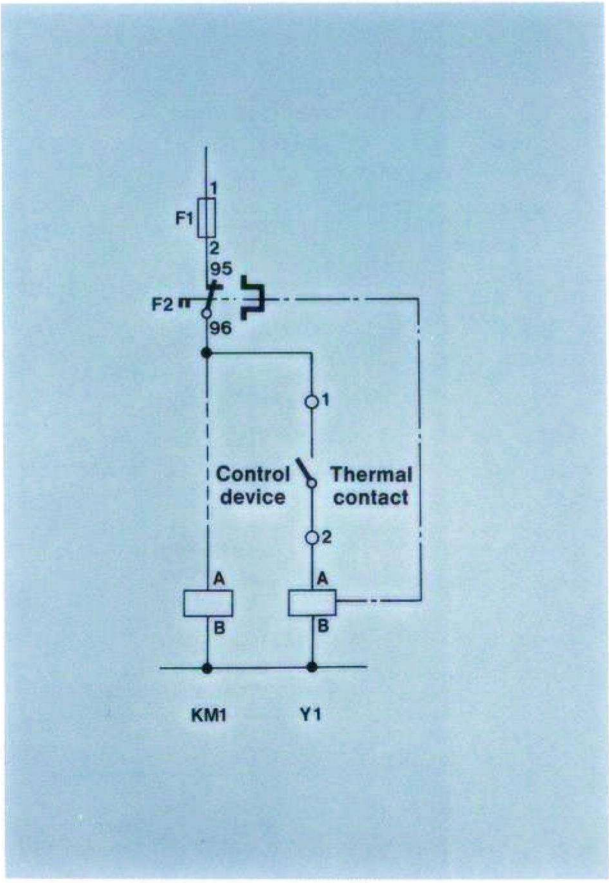
One or more bimetal thermal probes embedded in the windings of the motor detect temperature rises. When the temperature is too high the thermal contact makes, energizing the electromagnet of the remote trip Y1 mounted on the side of the thermal overload relay F2. Contact 95-96 of F2 opens causing contactor KM1 to open (see page 26).

- **Control circuit operation**

KM1 closed.
Abnormal heating of the motor.
Thermal contact (1-2) closes.
Energization of electromagnet of trip Y1.
Mechanical action of Y1 on contact 95-96 of F2.
Opening of KM1 by F2 (95-96).
Resetting of the contact, after cooling, by pressing push button of F2.

- **Required equipment**

Y1: 1 remote tripping device **LA7-D** or **ER1-F** mounted on the side of a thermal overload relay **LR1-D** or **RA1.**



Protection by bimetal thermal probe with control relay

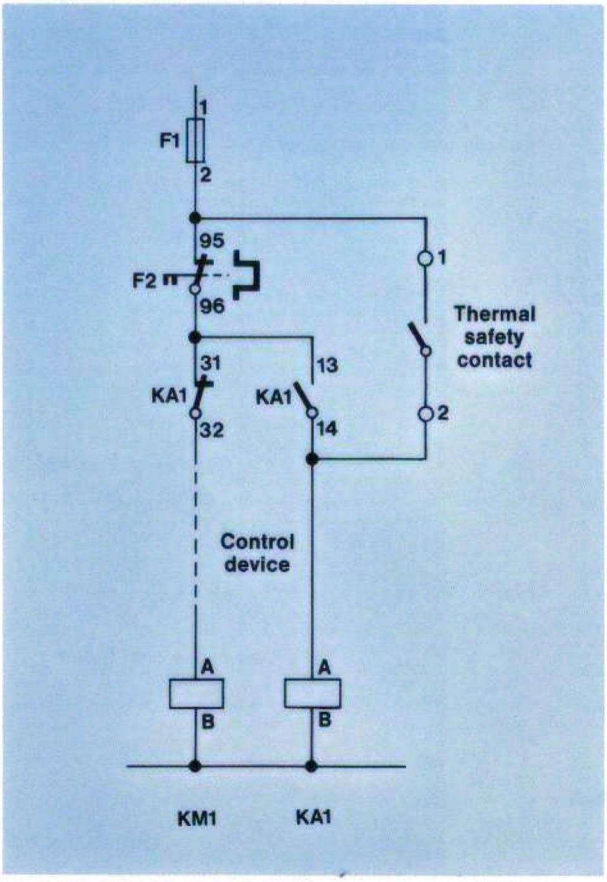
Same principle as above but the thermal contact controls the closing of a control relay KA1 whose N/C contact causes the opening of contactor KM1.

- **Control circuit operation**

KM1 closed.
Abnormal heating of the motor.
Thermal contact (1-2) closes, KA1 opens.
Opening of KM1 by KA1 (31-32).
Hold in of KA1 (13-14).
Resetting of the contact, after cooling, by pressing push button of F2.

- **Required equipment**

KA1: 1 control relay N/C + N/O
CA2-AN; CA2-DN; CA2-FN; etc.
F2: 1 thermal overload relay **LR1-D** or **RA1.**



Protection by PTC thermistor probes

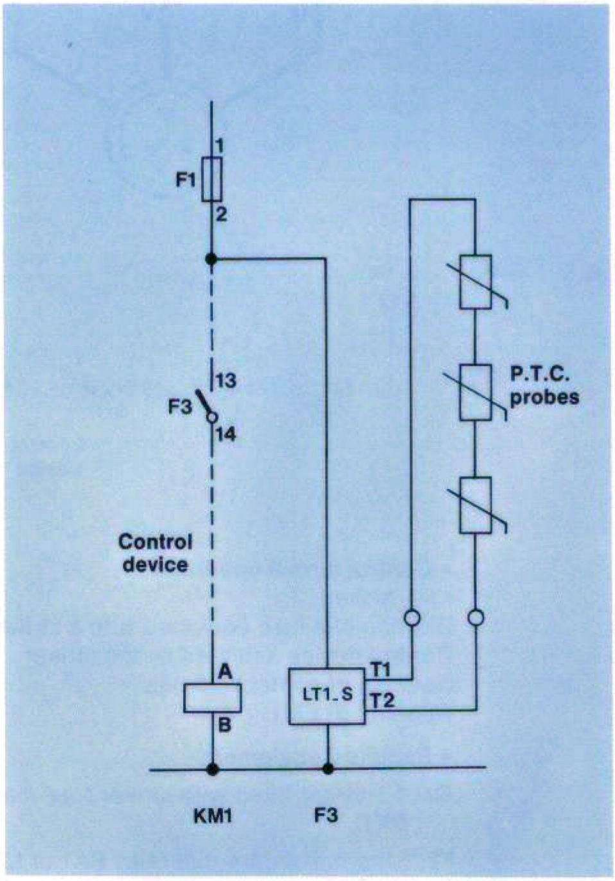
The bimetal thermal probes are replaced by three PTC probes (refer to page 29). As the motor windings heat up the resistance to these probes increases When a certain value is exceeded the relay contact incorporated in the protection relay F3 opens causing the opening of contactor KM1 which controls the motor.

- **Control circuit operation**

Contact 13-14 of F3 closed.
KM1 closed.
Abnormal heating of the motor.
Increase in resistance of PTC probes.
Opening of contact 13-14 of F3.
Opening of KM1 by F3 (13-14).
Automatic (LT1-SA) or manual (LT1-SP) reset after cooling of motor.

- **Required equipment**

F3: 1 relay **LT1-SA** or **LT1-SP.**



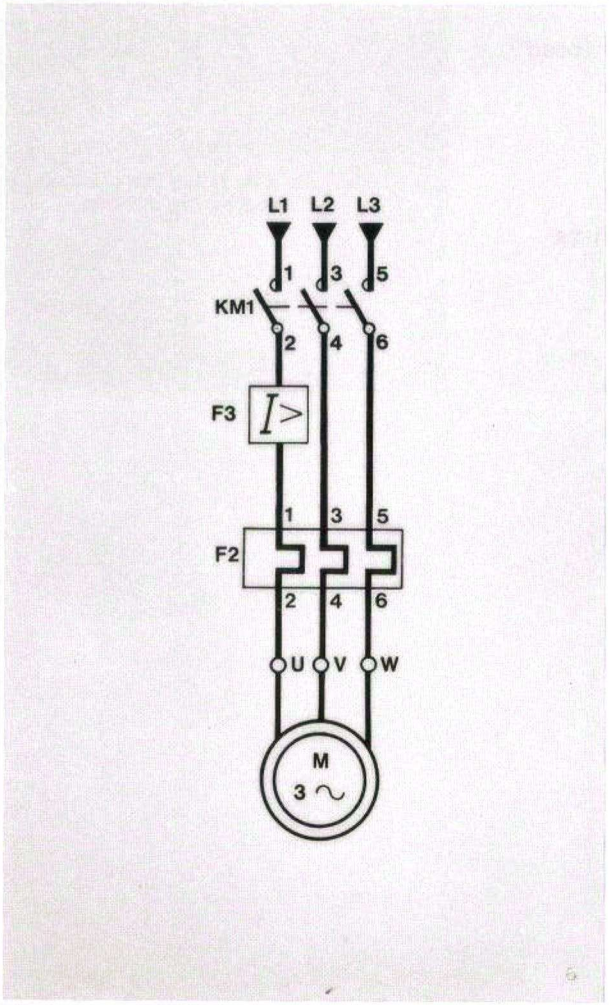
Protection by overcurrent (stalling) relay

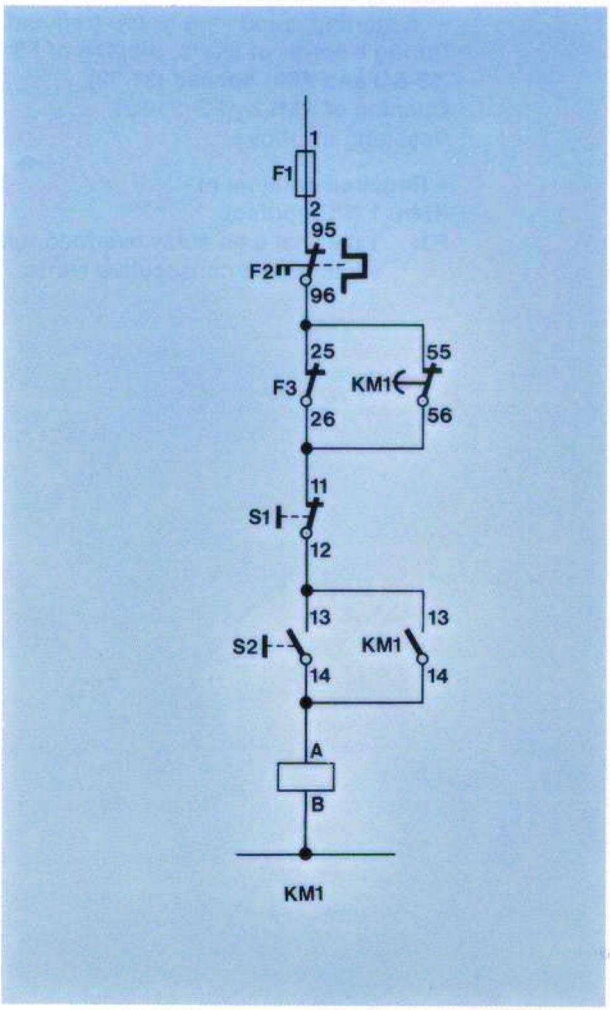
An overcurrent relay, connected in one of the lines, monitors the input current (see page 31).
Since the current increases with the load the relay is set to stop the motor when its input current reaches a predetermined value.

• Features
Since the motor input current during starting would close the relay its contact 25-26 should be shorted out by the time delay contact 55-56 until the starting cycle is complete.

• Control circuit operation
Closing of KM1.
Opening of F3 (25-26), without effect since it is shorted out by 55-56 of KM1.
Reclosing of F3 (25-26).
Opening of 55-56 of KM1, without effect since it is shorted out by 25-26 of F3.
Motor overload.
Closing of overcurrent relay F3.
Opening of KM1 by 25-26 of F3.

• Required equipment
KM1: 1 timing relay with time delay on energization.
F3: 1 overcurrent relay **RM1-J,** with trip point set above the rated motor input current.



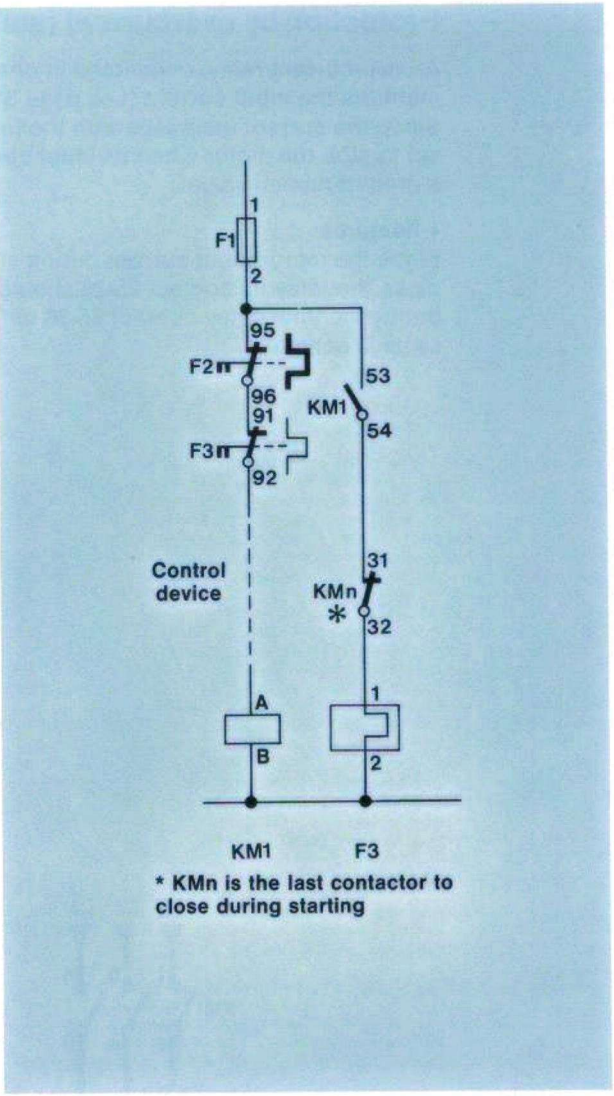


Protection of starting resistors or autotransformer

A thermal overload relay F3, whose bimetallic element is energized during the entire starting period, protects the resistors or autotransformer against too frequent starting (refer to page 43).

• **Control circuit operation**
Closing of KM1.
Energization of F3 by KM1 (53-54).
Closing of intermediate contactors used during starting in the case of an autotransformer or for short circuiting of resistors.
Closing of the last starting contactor KMn (autotransformer) or last short-circuiting contactor.
De-energization of F3 by KMn (31-32).
— In the case of incomplete starting:
KMn does not close.
F3 remains energized by KM1 (53-54) and KMn (31-32).
After about 30 sec., tripping of F3.
Opening of KM1 by 91-92 of F3.
Resetting by pressing the push button of F3 after cooling of the thermal relay element.
— If starting is too long or too frequent:
During a series of starts, tripping of F3; KM1 closed (53-54) and KMn opened (31-32).
Opening of KM1 by F3 (91-92).
Resetting as above.

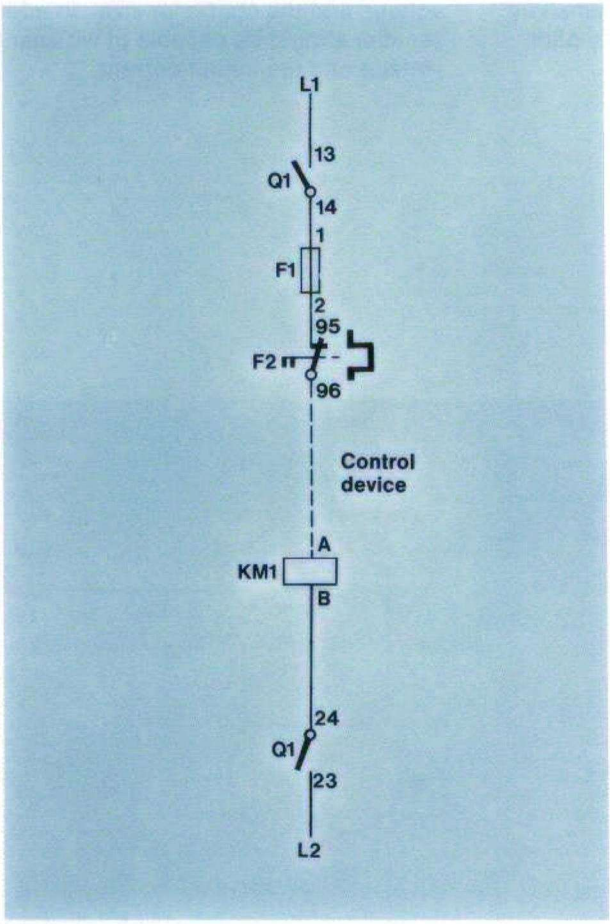
• **Required equipment**
KMn: 1 N/C contact.
F3: 1 thermal time delay overload relay **RT1-TK** set for 2 to 3 consecutive starts.



*** KMn is the last contactor to close during starting**

Connection across phases

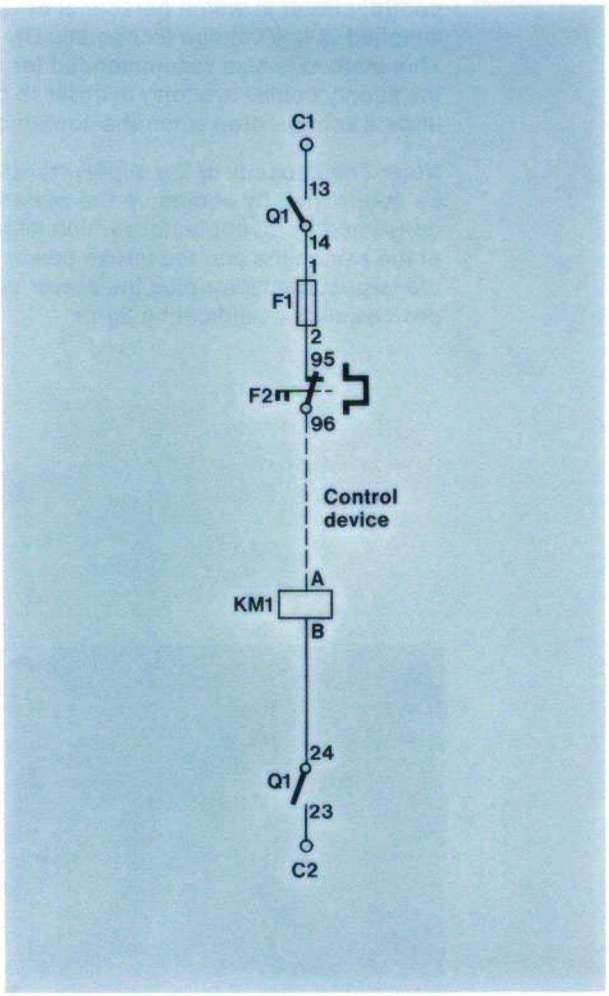
The control circuit may be connected across two phases of the main supply.
In practice L1 of the main supply is connected to terminal 13 of the first early break contact of isolator Q1 and L2 is connected to terminal 23 of the second early break contact.
If the equipment does not include an isolator L1 is connected to terminal 1 of the fuse F1 and L2 to terminal B of the contactor KM1.



Separate supply

The control circuit may be connected to a supply separate to that of the power circuit. It is connected to this separate source by terminals C1 and C2 connected respectively to terminal 1 of the fuse F1 and terminal B of the contactor KM1.

• If necessary the contactor coils should be replaced if the source of supply to the control circuit is altered.



Transformer supply

When as a safety precaution it is necessary to supply the contactor and its control circuit, particularly the pilot devices, with a voltage lower than that of the main supply, a transformer can be used whose primary is connected to the main supply and whose secondary supplies the control voltage.

Two possibilities:

• the panel contains one or two small contactors. In this case the required transformer capacity is low and the contactors can be connected to it directly (schematic A, page 116).

connection of the control circuit

• the panel contains one or more large contactors or many small contactors. It is then wiser, in order to limit the size of the transformer, to supply a control relay (KA1) at the reduced voltage and this energizes the contactors.
These contactors are fitted with coils which operate at the main supply voltage and only that part of the control circuit to which personnel have access is supplied at low voltage (schematic B).
This method is also recommended for cases in which the supply cables are long in order to prevent too large a voltage drop when the contactors close.

Note: The capacity of the supply transformer should be determined by adding up the sealed power consumed by all contactors which might be closed at the same time and the inrush power consumed by the largest contactor plus the power taken by pilot devices such as indicating lights.

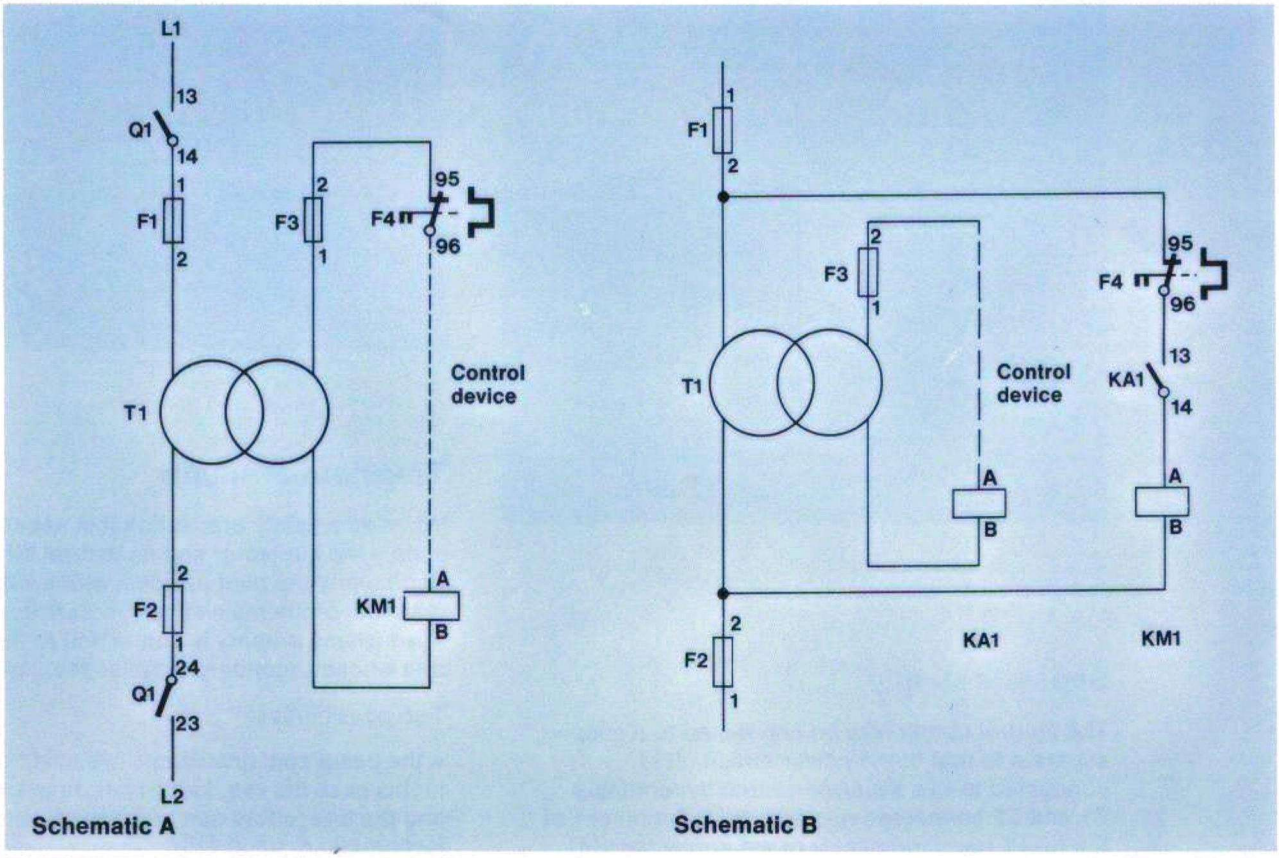
Rectified supply
(schematic C)

This method is used with contactors of all sizes to obtain silent operation as well as to supply large contactors for which it permits:

• a considerable increase in pole pressure;

• holding the contactor closed even in the case of a substantial drop in the control voltage;

• a short delay in the opening of the contactor during a transient voltage failure (the coil is connected to the terminals of the rectifier).
The rectifier and coil as well as the economy resistor, which reduces power consumption (refer to page 13), should be selected in relation to the voltage and the contactor size. In addition the rectifier should be capable of withstanding the main voltage and the inrush current.

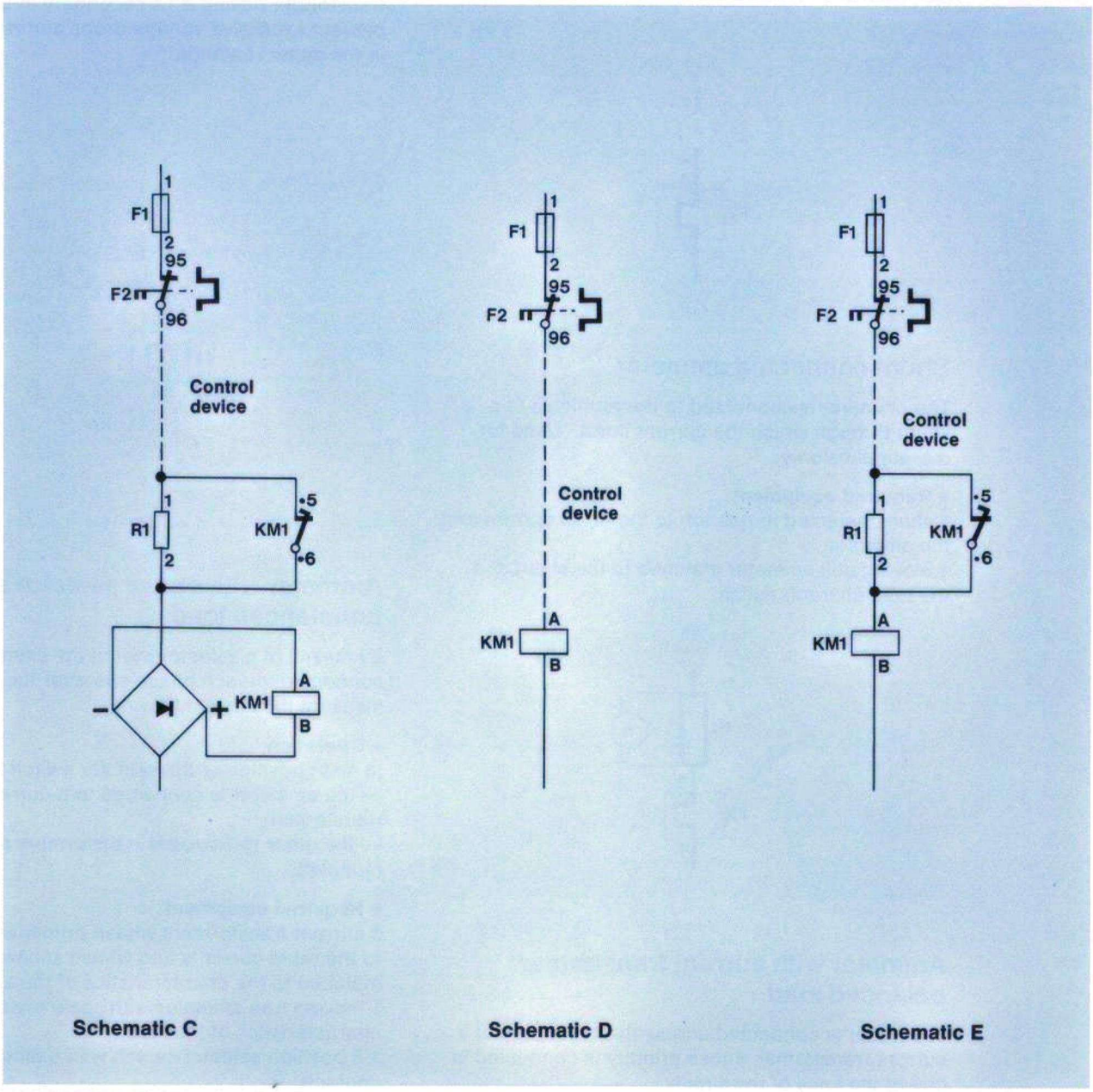


D.C. supply without economy resistor
(schematic D)

There is no economy resistor since the magnetic circuit has been specially designed for full voltage d.c. operation and the coil is designed for continuous duty.
D.C. contactors without economy resistors should be used when the rate of operation is high and an extended life is required.

D.C. supply with economy resistor
(schematic E)

A resistor connected in the coil circuit as soon as the contactor is closed (opening of contact 5-6) limits consumption.
The opening of the contact which inserts the economy resistor should occur after the closing of the contactor, at the midpoint of the compression travel of the poles (refer to page 10).
A contactor fitted with an economy resistor should not be switched more than thirty times per hour.



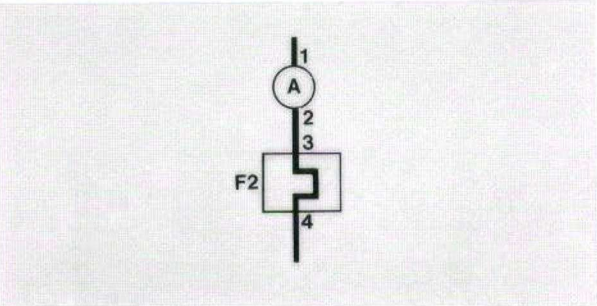
Directly connected ammeter

The ammeter, connected in one of the lines of the supply, indicates the current input. In a balanced three phase circuit only a single meter is required. This circuit is used with a.c. or d.c.

- **Required equipment**

Alternating current:
Moving iron ammeter.

Direct current:
Moving coil ammeter.

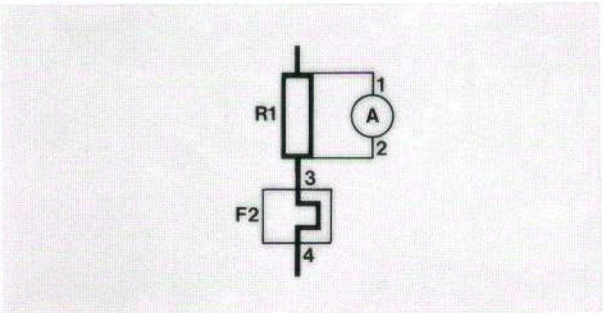


Shunt connected ammeter

The ammeter is connected to the terminals of a shunt through which the current flows. Used for d.c. supplies only.

- **Required equipment**

1 shunt, selected in relation to the rated current and the ammeter.
1 moving coil ammeter matched to the shunt and the load characteristics.



Ammeter with current transformer: balanced load

The meter is connected across the secondary of a current transformer whose primary is connected in one of the lines of the supply.

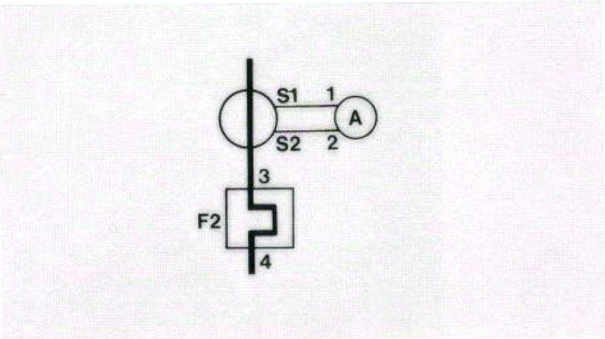
As above, in a balanced three-phase circuit only a single meter is required. Used for a.c. only.

Caution: The secondary of the current transformer should always be loaded; in the absence of an ammeter connect a shunt across the terminals.

- **Required equipment**

1 current transformer with the primary matched to the load current and the secondary matched to the characteristics of the ammeter.
1 moving iron ammeter with scale matched to the load.

Note: If the distance between the ammeter and current transformer is greater than 4 m use a transformer having a 1A secondary in order to prevent excessive voltage drops and resulting errors in the meter readings.



Ammeter with phase selector switch - unbalanced load

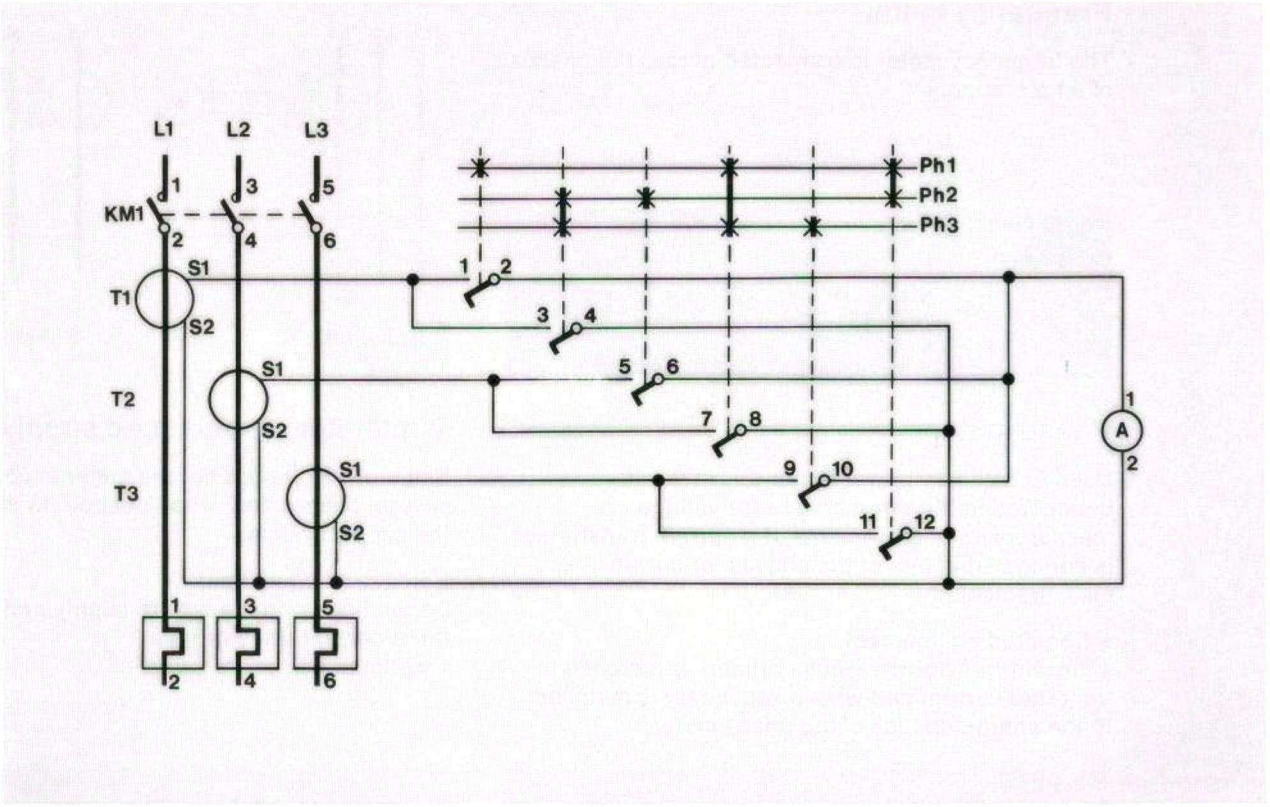
By means of a selector switch the ammeter is connected to each phase one after the other to measure the current flowing.

- **Operation**

In each position of the selector switch S1:
— the ammeter is connected to a current transformer;
— the other two current transformers are short circuited.

- **Required equipment**

3 current transformers whose primaries are matched to the rated currents and whose secondaries are matched to the characteristics of the ammeter.
1 moving iron ammeter with scale matching the characteristics of the load.
1-3 position selector switch with 6 make before break contacts.



Voltmeter with phase selector - measurement across phases

By means of a selector switch the voltmeter is connected across two phases in turn.

- **Required equipment**

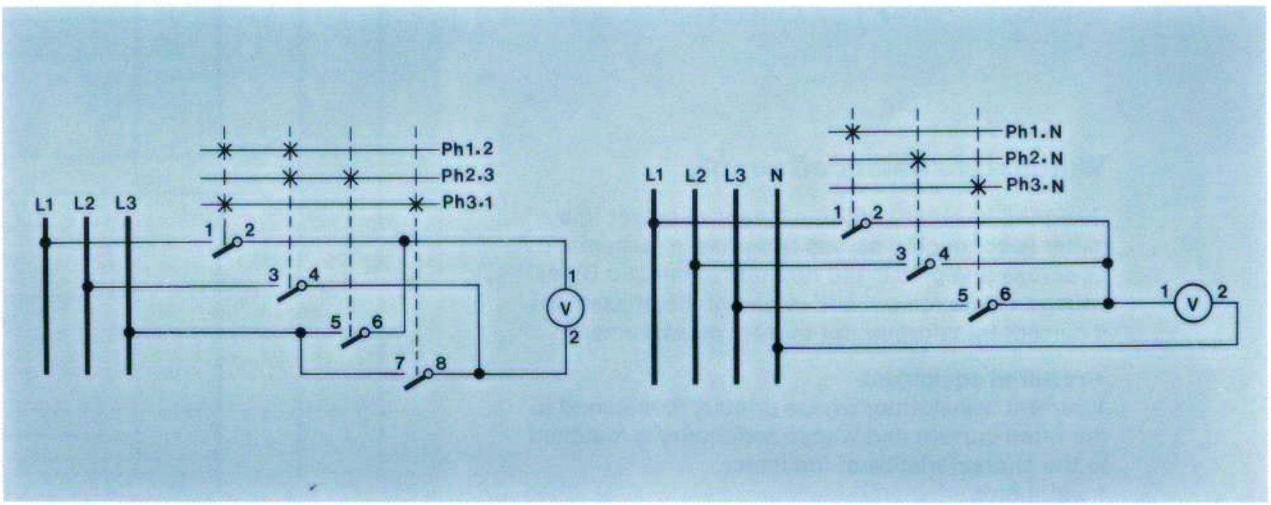
1 moving iron voltmeter matched to the line voltage.
1-3 position switch with 4 break before make contacts.

Voltmeter with phase selector switch: measurement across phase and neutral

Same principle as before but the measurement is made across one phase and neutral.

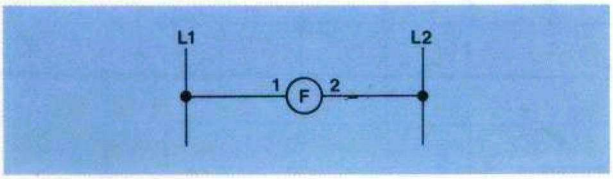
- **Required equipment**

1 moving iron voltmeter matched to the line voltage.
1-3 position switch and 3 break before make contacts.



Frequency meter

The frequency meter is connected across the phases of an a.c. supply.

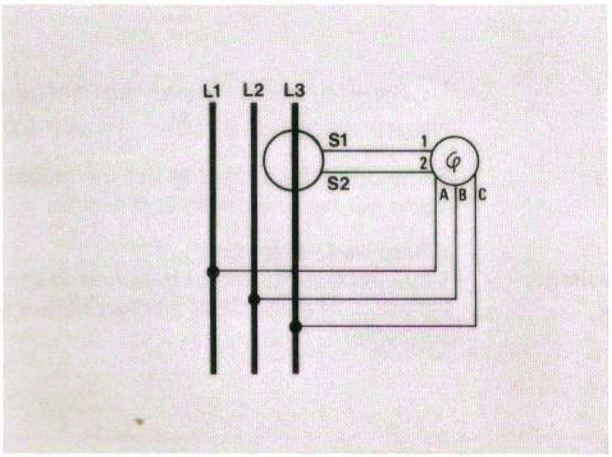


Phase meter

Used to measure power factor this meter is connected to the three phases for voltage measurement and by means of a current transformer is connected in one of the phases for current measurement.

- **Required equipement**

1 current transformer whose primary is matched to the rated current and whose secondary is matched to the characteristics of the phase meter.

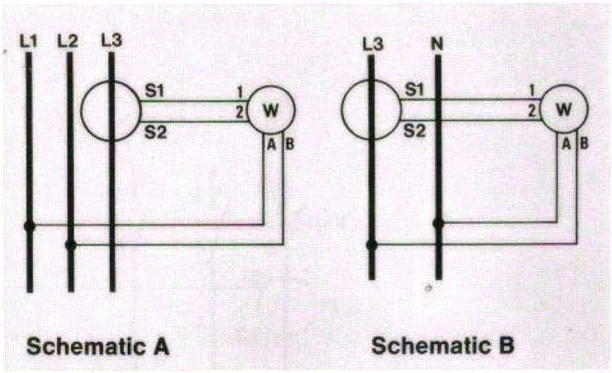


Wattmeter - balanced supply

Designed to record active or reactive power this meter is connected across two phases (schematic A) or across one phase and neutral (schematic B) for voltage measurement and in one of the phases, via a current transformer, for current measurement.

- **required equipment**

1 current transformer whose primary is matched to the rated current and whose secondary is matched to the characteristics of the meter.
1 wattmeter.

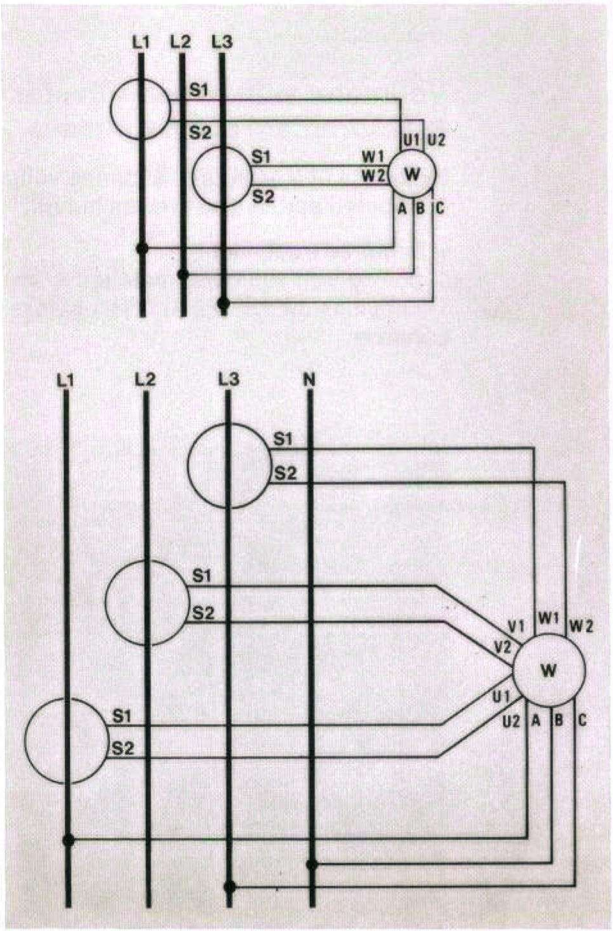


Wattmeter: unbalanced supply

Same use as before but the meter is connected to several phases and, when desired, to the neutral of the supply system.

- **Required equipment**

Depending upon the type of supply system, two or three current transformers.
1 wattmeter.



Emergency lighting

This equipment substitutes a standby supply, often from a d.c. source such as a battery.
In areas frequented by the public i.e. theatres, department stores, etc., emergency lighting should be put into service when the voltage of the main supply falls below a specified level, typically 70% of the nominal supply.

POWER CIRCUIT OPERATION

— In the presence of the main supply:
KM1 closed.
Poles of KM1 open.
— When the main supply fails:
Opening of KM1.
Poles of KM1 closed. Supply of the lighting circuit by the standby source.
— When the main supply is restored:
Closing of KM1.
Poles of KM1 open (schematic A).

- **Features**

Contactor KM1 equipped with N/C poles.
If the standby supply is d.c., blow out coils of the contactor poles should be calibrated in relation to the load.
A voltage sensing relay, opening at 70% of the nominal supply, may be incorporated (schematic B).

REFERENCES OF AVAILABLE EQUIPMENT

- **Preassembled units**

NL1-FA - with or without isolator.

- **Enclosed equipment**

NL1-FA - with or without isolator - sheet steel or insulated enclosure.

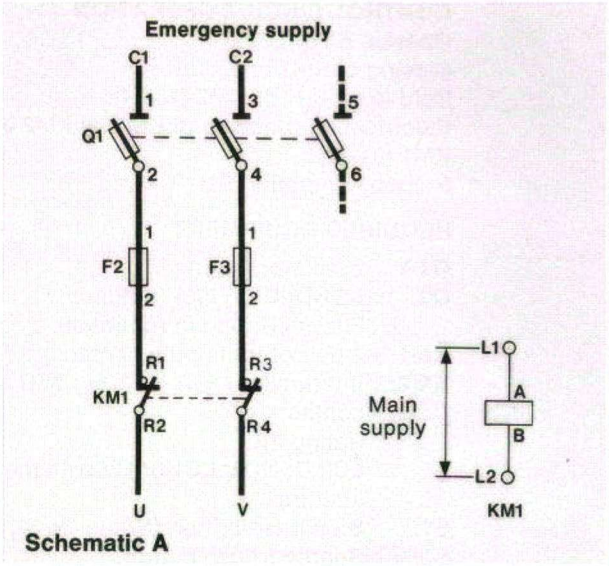
REQUIRED EQUIPMENT
(Schematic A)

Q1: 1 triple pole isolator (optional) - Rating In.:
LS1-D; DK1; LK1.
2 fuses - Rating In (optional).

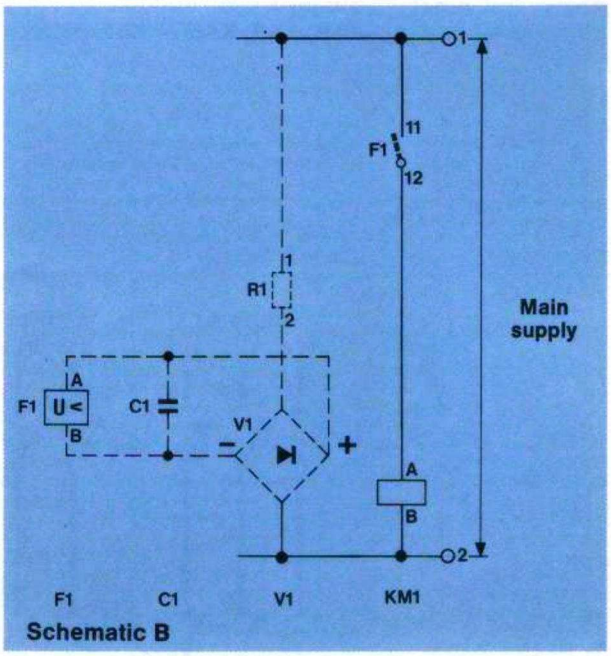
KM1: 1 contactor with 2 N/C poles - Rating In.:
CV1.
Blow out coils matched to load current.

(Schematic B)
In addition to the above equipment:

F1: 1 voltage sensing relay **RN1-BA.** Operating coil matched to the line voltage. Relay set to 0.7 of the main supply.



Schematic A



Schematic B

Change over panel

This panel is used when two supplies are available and the choice is made manually. The circuit is common as is the stop push button which opens the reversing contactors.

POWER CIRCUIT OPERATION

Closing of KM1 or KM2.

- **Features**

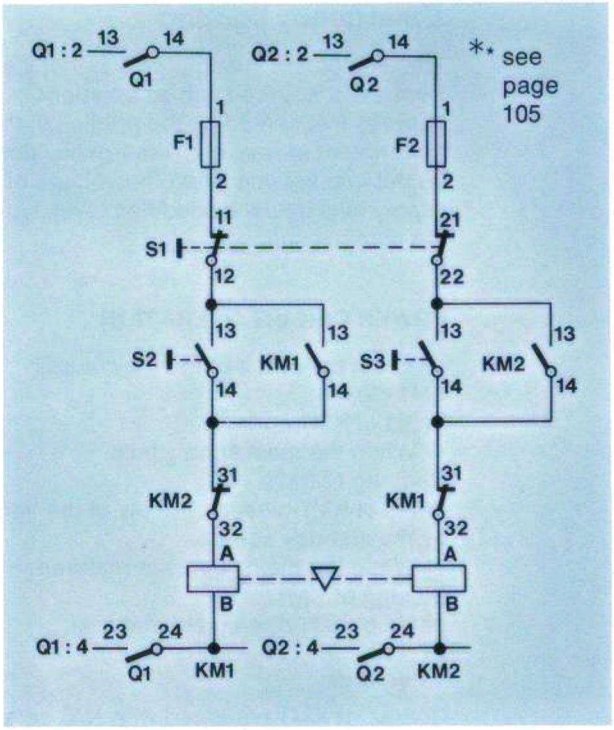
KM1-KM2: rated for load power and mechanically interlocked.
Q1-Q2: rated for load power.

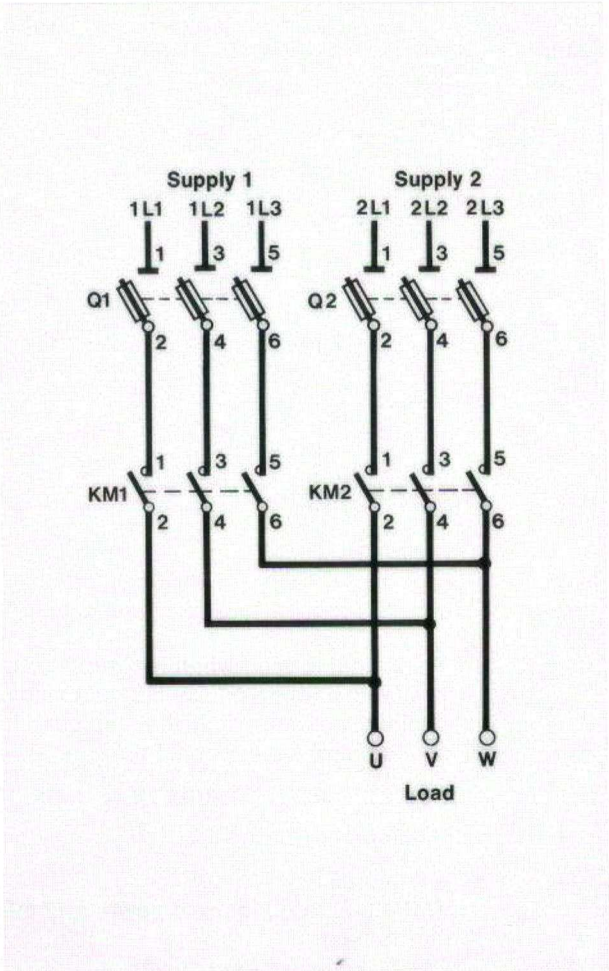
CONTROL CIRCUIT OPERATION

Operate S2 or S3.
Closing of KM1 or KM2.
Hold in of KM1 or KM2 (13-14).
Electrical interlocking of KM1 by KM2 or of KM2 by KM1 (31-32).
Stop: by operating S1.

REQUIRED EQUIPMENT

Q1+ 2 isolators rating In.
Q2: **LS1-D; DK1; LK1** (optional).
Fuses - Rating In (optional).
KM1+ 1 pair of triple pole contactors (mechanically
KM2: interlocked) + 1 N/C + 1 N/O auxiliary contacts.
Rating In:
LC2-D; NC2; LC1 or **CV** with mechanical interlock.
S1: Stop push button (N/C + N/C).
S2: Supply 1 push button.
S3: Supply 2 push button.
XAB; XAF; XAG or **XB2,** etc.





"Main-Standby" equipment

This panel provides for automatic changeover from main (normal) to standby (emergency) supply and vice versa. Two separate supplies are available depending upon requirements, the control circuit can be separate or common to both supplies.

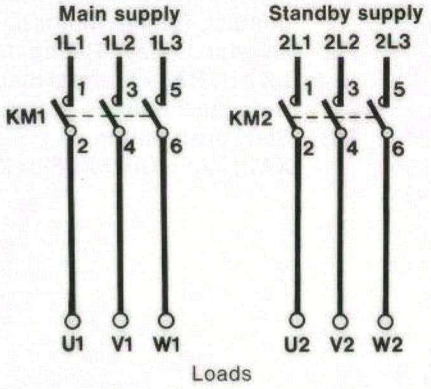
POWER CIRCUIT OPERATION

(Identical to that of the changeover panel on the preceding page.)

CONTROL CIRCUIT OPERATION

— In the presence of the main supply:
KA1 closes.
Electrical interlocking of KM2 by KA1 (31-32).
Closing of KM1 by KA1 (67-68).
Electrical interlocking of KM2 by KM1 (31-32).
— Upon failure of the main supply:
Opening of KA1 and KM1.
Closing of KM2 and KA1 (31-32) and KM1 (31-32).
Electrical interlocking of KM1 by KM2 (31-32).
— Upon restoration of the main supply:
Closing of KA1.
Opening of KM2 by KA1 (31-32).
Closing of KM1 by KA1 (67-68) after a time delay of approximately 0.5 sec.
Electrical interlocking of KM2 by KM1 (31-32).

• Features
The purpose of the time delay at the moment of changeover from standby to main is to prevent the paralleling of the supplies.



REFERENCES OF AVAILABLE EQUIPMENT

• Open type equipment
NL2 - With or without isolator.

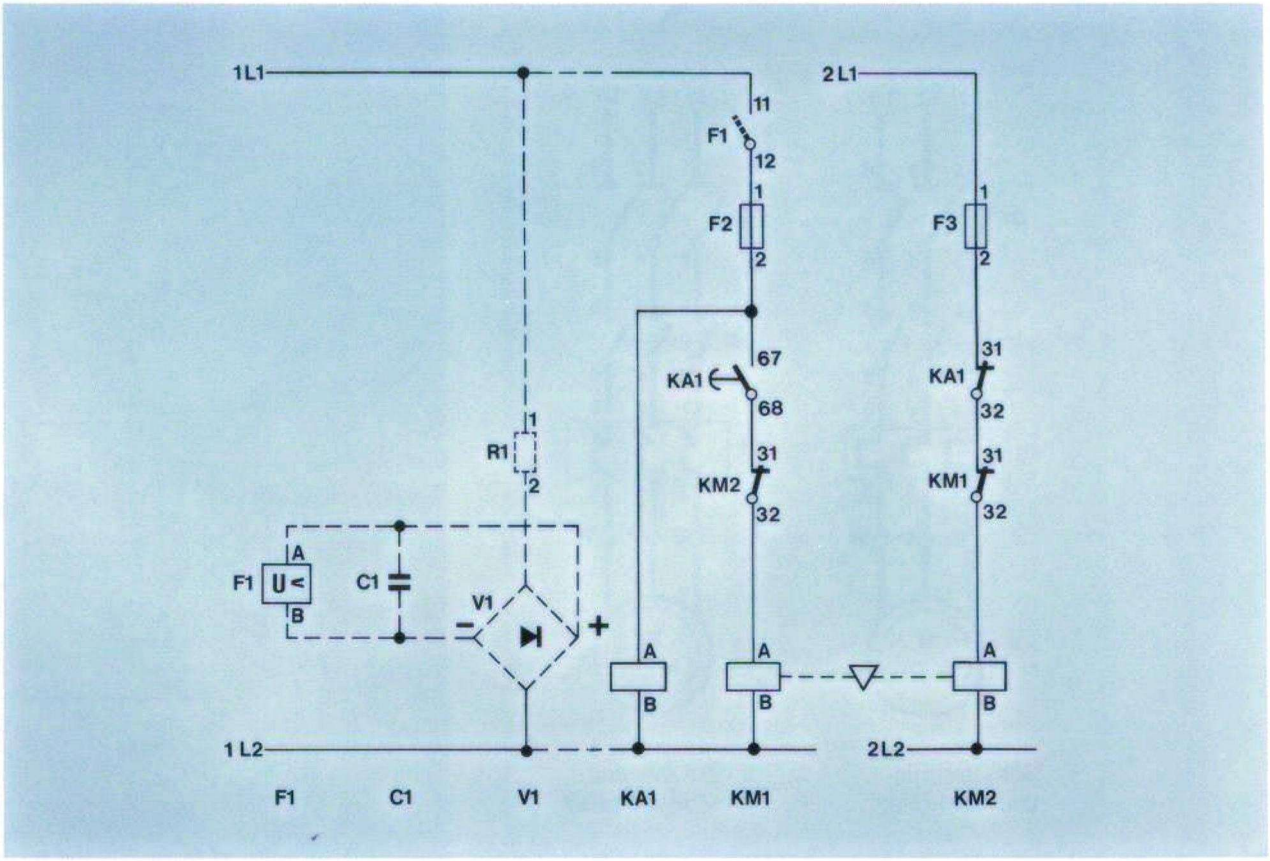
• Enclosed equipment
NL2 - With or without isolator - sheet steel or insulated enclosure.

REQUIRED EQUIPMENT

KM1 + 1 pair of 3 or 4 pole contactors with 1-N/C
KM2: auxiliary contact.
Rating In:
LC2-D or NC2
or 2 contactors having 2, 3 or 4 main poles with 1-N/C auxiliary contact: mechanically interlocked **CV1** or **LC1-B.**

KA1: 1 timing relay with time delay on energization **CA2-AN + CA2-AS22; CA2-DN + LA2-D22; CA2-FT,** etc.
Approximate time delay 0.5 sec.

F1: 1 voltage sensing relay **RN1-BA** (optional).
Operating coil matched to the line voltage.
Relay set to 0.7 of the main supply.



Direct on line starter

POWER CIRCUIT OPERATION

Manual closing of Q1.

- **Features**

Q1: Rating, Motor In.
KM1: Rating, Motor In, taking the utilization category into account.
F2: Rating, Motor In.

CONTROL CIRCUIT OPERATION

Operate S2.
Closing of KM1.
Hold in of KM1 (13-14).
Stop: operate S1.

REFERENCES OF AVAILABLE EQUIPMENT

- **Open type units**

Pre-wired contactor and isolator.
Without thermal overload relay:
LC4-D, etc.

- **Enclosed equipment**

With or without isolator (internal or external handle).
Without thermal overload relay. **LE1-D ; LE4-D** or **NC1.**
With or without isolator (internal or external handle).
With thermal overload relay. **LE1-D; LE4-D** or **ND1.**

Note: LE1-D and **LE4-D** are also available in four pole versions.

REQUIRED EQUIPMENT

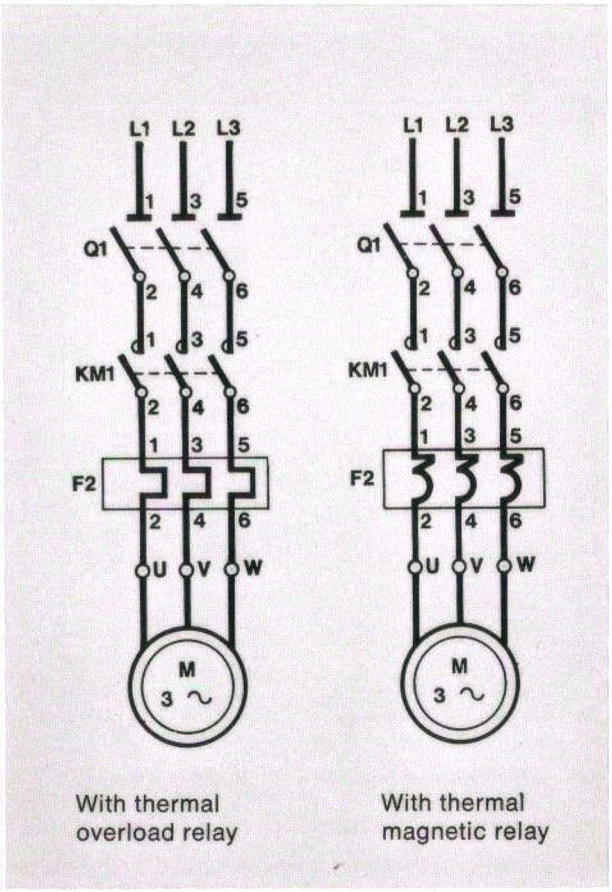
Q1: 1 isolator, 3 or 4 pole (optional).
Rating: Motor In : **LS1-D** or **DK1.**
3 or 4 main fuses (optional).
Rating: Motor In.

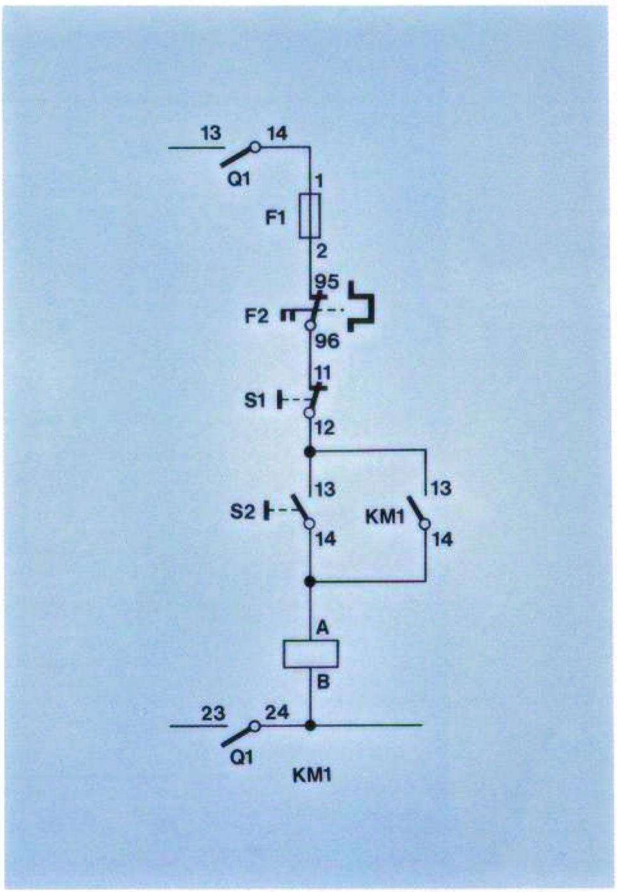
KM1: 3 or 4 pole contactor with 1 N/O auxiliary contact, Rating: Motor In : **LC1; CN; CV.**

F2: Overload relay. Rating: Motor In - thermal; **LR1-D; RA1** - thermal magnetic: **RMT-D.**

S1: Stop push button.

S2: Start push button.
XAB; XAF; XAG; XBF or **XB2-M,** etc.





starting of squirrel cage motors

Direct on line reversing starter

POWER CIRCUIT OPERATION

Manual closing of Q1.

- **Features**

Q1: Rating - Motor In.
KM1-KM2: Rating - Motor In. taking the utilization category into account.
F2: Rating - Motor In.
Mechanical interlock between KM1 and KM2.

CONTROL CIRCUIT OPERATION

Operate S2 or S3.
Closing of KM1 or KM2.
Hold in of KM1 or KM2 (13-14).
Electrical interlocking of KM1 by KM2 or KM2 by KM1 (31-32).
Manual stop: operate S1.
Automatic stop by limit switch S4 or S5 (page 126).

REFERENCES OF AVAILABLE EQUIPMENT

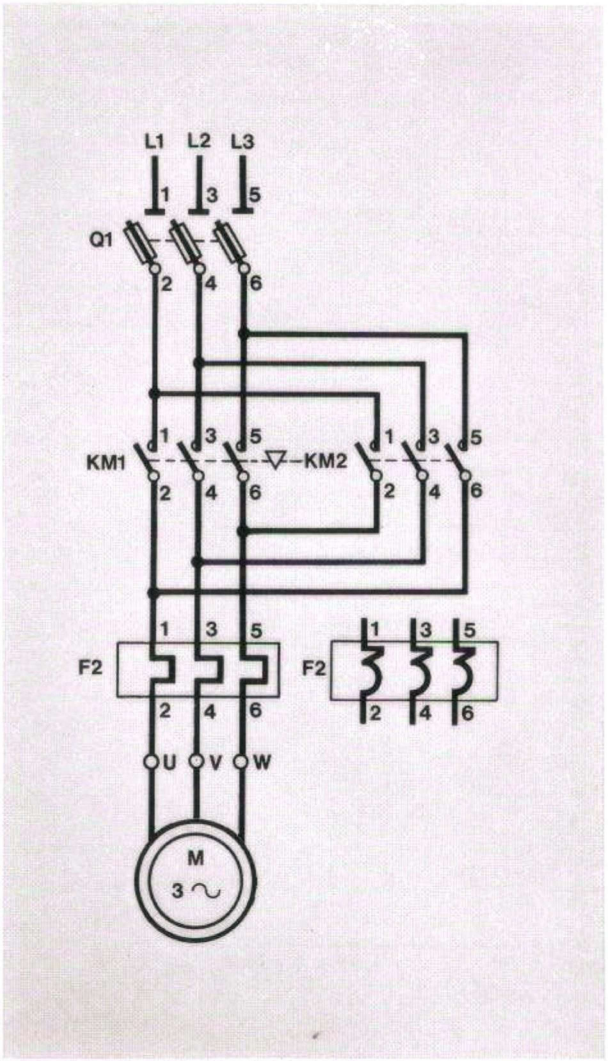
- **Open type units**

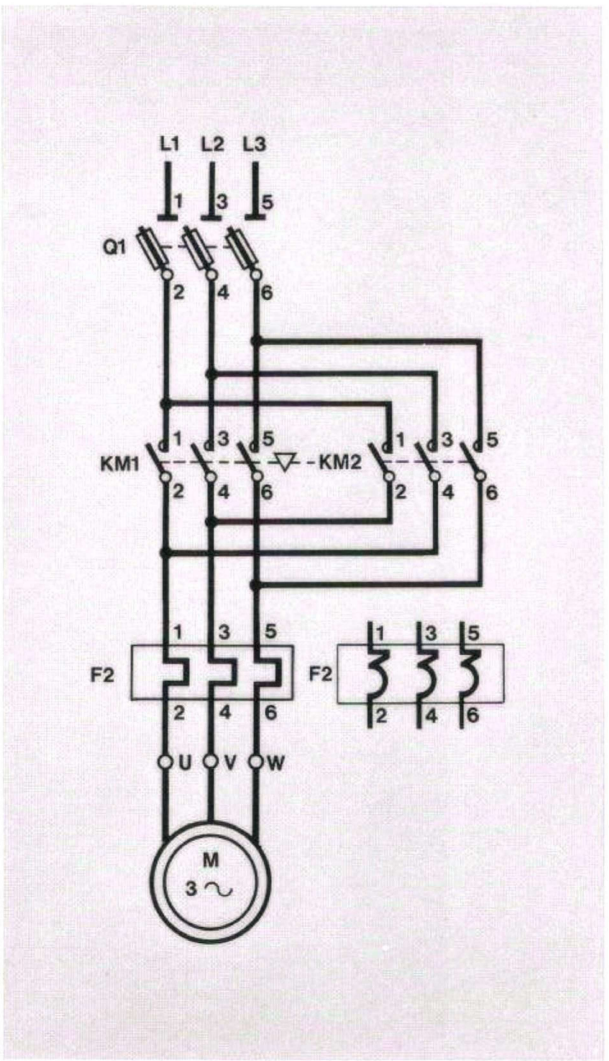
Prewired contactors with mechanical interlock: **LC2-D** or **NC2.**

- **Enclosed equipment**

With or without isolator (internal or external handle) Without thermal overload relay. **LE2-D** or **NC2.**
With or without isolator (internal or external handle) With thermal overload relay. **LE2-D** or **ND2.**

Note: LE2-D is also available in a four pole version.





REQUIRED EQUIPMENT

Q1: 1 isolator (optional). Rating: Motor In.
LS1-D or **DK1.**
3 main fuses (optional). Rating: Motor In.

KM1 + 1 pair of triple pole contactors (mechanically
KM2: interlocked) + N/C + N/O auxiliary contacts. Rating In.
LC2-D; NC2; or 2 contactors, **LC1** or **CV** with mechanically interlock.

F2: 1 overload relay. Rating: Motor In:
— thermal: **LR1-D; RA1,**
— thermal magnetic: **RMT-D.**

S1: Stop push button.

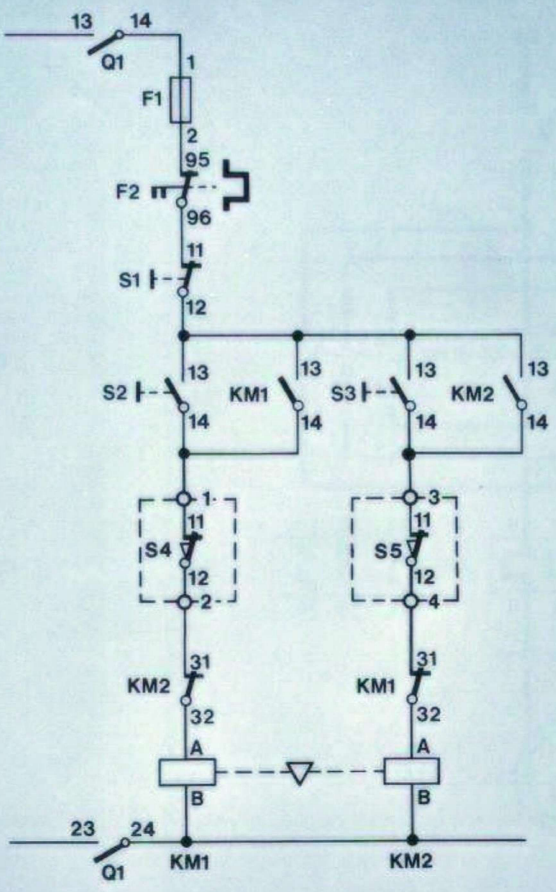
S2: Forward push button.

S3: Reverse push button.
XAB; XAF; XAG; XBF or **XB2-M,** etc.

S4 + Automatic Pilot devices.

S5: **XC1; XC2; XCE; XCK; XF1; X** Series detectors, etc.

* see page 105



Star delta starter

POWER CIRCUIT OPERATION
(schematics A, B and C)

Manual closing of Q1.
Closing of KM1 - star connection.
Closing of KM2 - line connection.
Opening of KM1 - opening of star connection.
Closing of KM3 - delta connection.

- **Features**

The voltage permissible across the windings connected in delta should correspond to the main supply voltage.

Q1 - Rating: motor In in Δ

F2 - Rating: motor In in Δ (schematic C), or

$$\frac{\text{motor In in } \Delta}{\sqrt{3}}$$

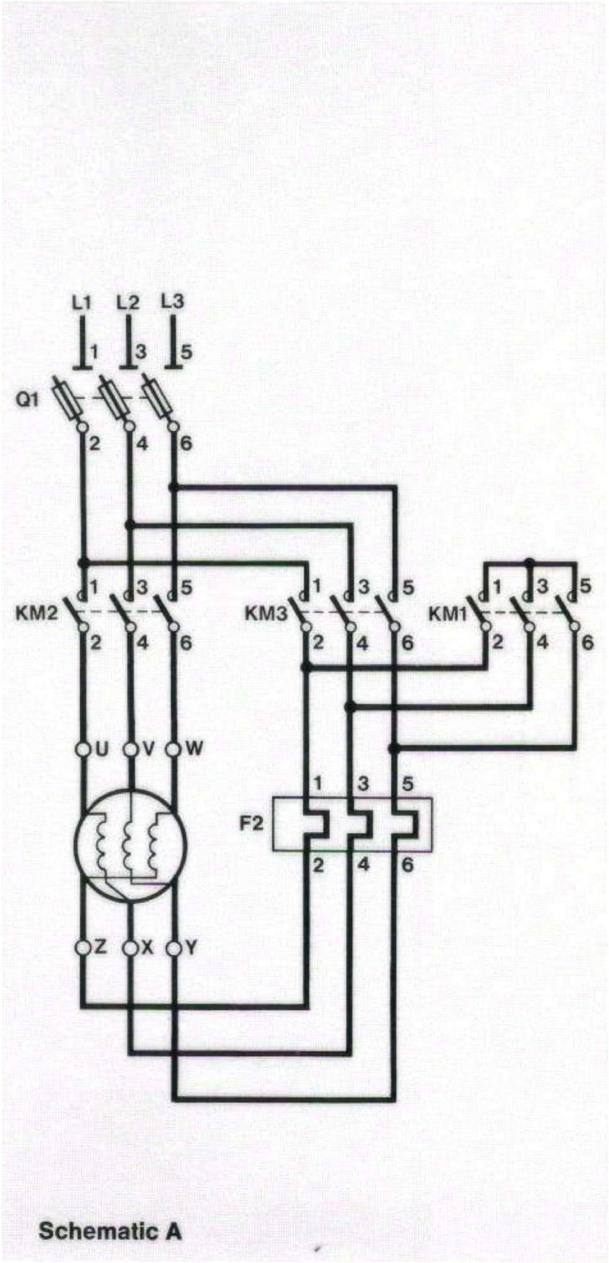
(schematics A and B).

KM1 - Rating:

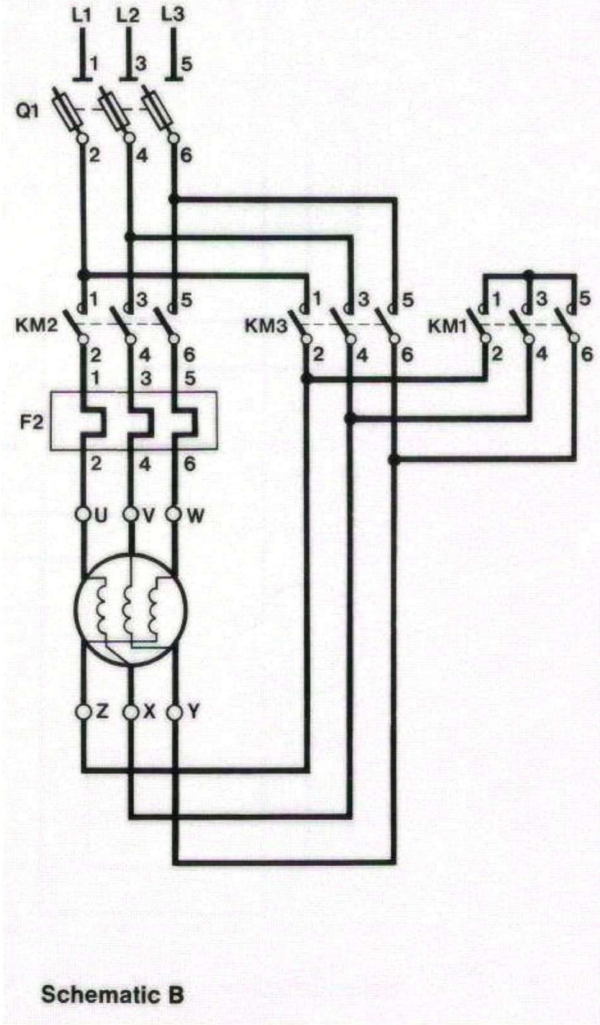
$$\frac{\text{motor In in } \Delta}{3}$$

KM2-KM3 - Rating:

$$\frac{\text{motor In in } \Delta}{\sqrt{3}}$$



Schematic A



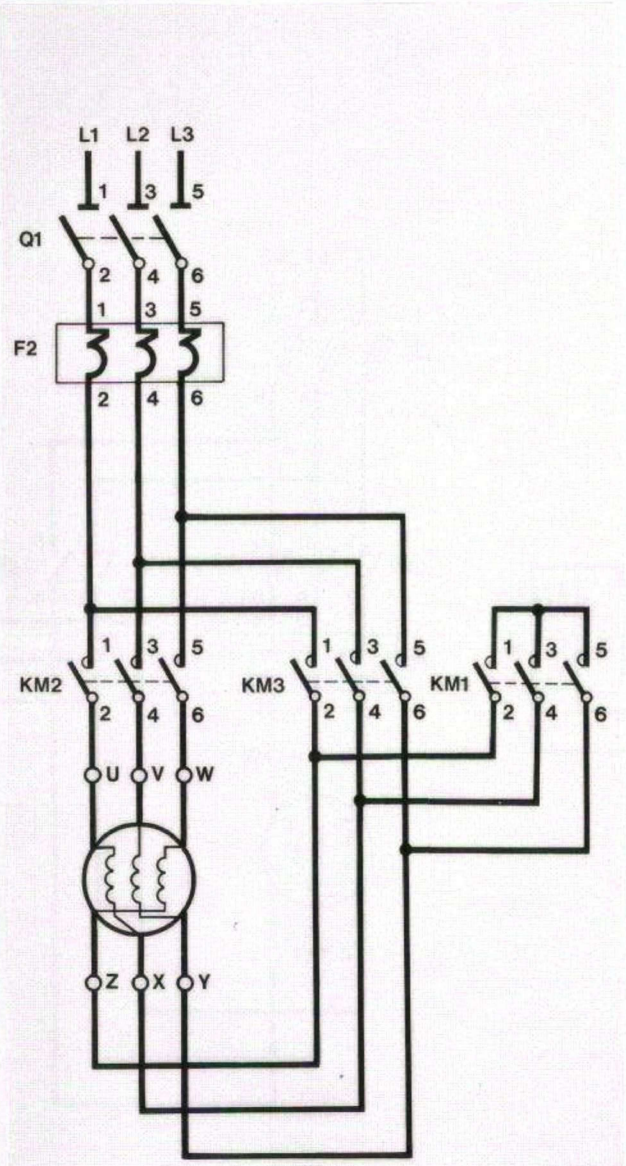
Schematic B

CONTROL CIRCUIT OPERATION
(schematic D)

Operate S2.
Closing of KM1.
Closing of KM2 by KM1 (13-14).
Hold in of KM1-KM2 by KM2 (13-14).
Opening of KM1 by KM2 (55-56).
Closing of KM3 by KM1 (31-32).
Stop: by operating S1.

- **Features**

Electrical interlock between KM1 and KM3.
Mechanical interlocking between KM1 and KM3 is also required to meet certain standards.



Schematic C

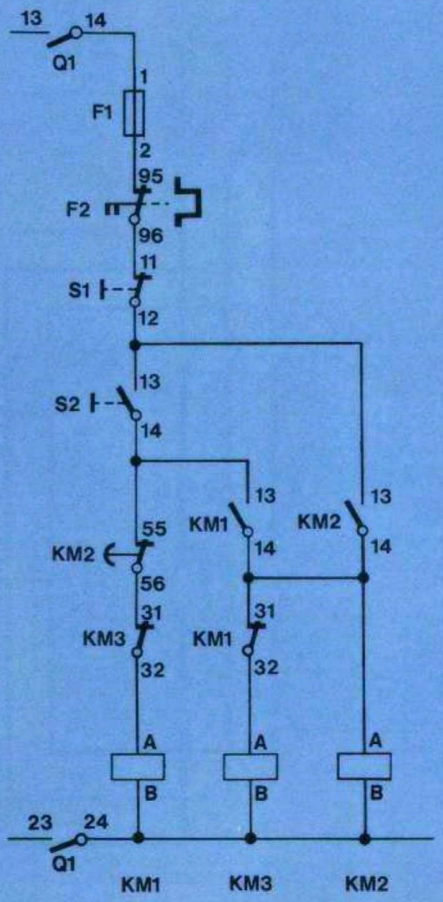
CONTROL CIRCUIT OPERATION
(schematic E)

Operate S2.
Closing of KM1.
Closing of KM2 and KA1 by KM1 (13-14).
Hold in of KM1, KM2 and KA1 by KM2 (13-14) and KA1 (13-14).
Opening of KM1 by KA1 (55-56).
Closing of KM3 by KM1 (31-32).
Stop: by operating S1.

- **Features**

Electrical interlock between KM1 and KM3.
Mechanical interlock recommended.

* see page 105



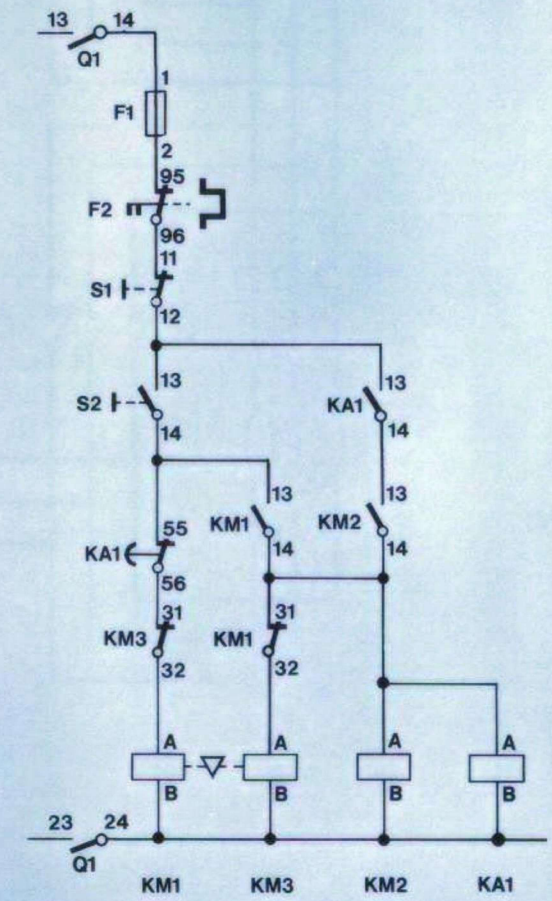
Schematic D

REFERENCES OF AVAILABLE EQUIPMENT

- **Open type starters**
3 prewired contactors; without isolator.
LC3-D or **NE1.**

- **Enclosed equipment**
With or without isolator (internal or external handle).
LE3-D or **NE1.**

* see page 105



Schematic E

REQUIRED EQUIPMENT

Q1: 1 triple pole isolator (optional).
Rating: Motor In in Δ
LS1-D; DK1.
3 fuses (optional). Rating: Motor In in delta.

KM1: 1 triple pole contactor with 1 N/C and 1 N/O auxiliary contacts.
Rating: $\frac{\text{motor In in } \Delta}{3}$
LC1, CN or **CV1.**

KM2: 1 triple pole contactor with 1 N/O auxiliary contact plus an auxiliary block with time delay on energization.
Rating: $\frac{\text{motor In in } \Delta}{\sqrt{3}}$
LC1, CN or **CV1.**
When using LC1-F or CN1 a separate timing relay should be used.

KM3: 1 triple pole contactor with 1 N/C auxiliary contact.
Rating: $\frac{\text{motor In in } \Delta}{\sqrt{3}}$
LC1, CN or **CV1.**
Mechanical interlock between KM1 and KM3 is recommended therefore **LC2-D** or **NC2** should be used.

KA1: 1 control relay with time delay on energization (only if KM1 is type LC1-F or CN contactor).
CA2-AN + CA2-AS22; CA2-DN + LA2-D2 or **CA2-FT.**
Approximate time delay 7 to 15 sec.

F2: In series with the motor windings (schematics A and B).
1 thermal overload relay.
Rating: $\frac{\text{motor In in } \Delta}{\sqrt{3}}$
LR1 or **RA1.**

S1: Stop push button.

S2: Start push button.
XAB; XAF; XAG; XBF or **XB2-M,** etc.

Star delta reversing starter

POWER CIRCUIT OPERATION
(schematics A, B and C)

Manual closing of Q1.
Closing of KM1 or KM2 - choice of direction of rotation.
Closing of KM3 - star connection.
Opening of KM3 - opening of star connection.
Closing of KM4 - delta connection.

- **Features**

Motor with 6 output terminals.
The voltage permissible across the windings connected in delta should correspond to the main supply voltage.
Q1 - Rating: Motor In in delta.
KM1 and KM2 - Rating: Motor In in △.
KM3 - Rating: $\frac{\text{Motor In in } \Delta}{3}$

KM4 - Rating: $\frac{\text{Motor In in } \Delta}{\sqrt{3}}$

F2 - Rating: $\frac{\text{Motor In in } \Delta}{\sqrt{3}}$

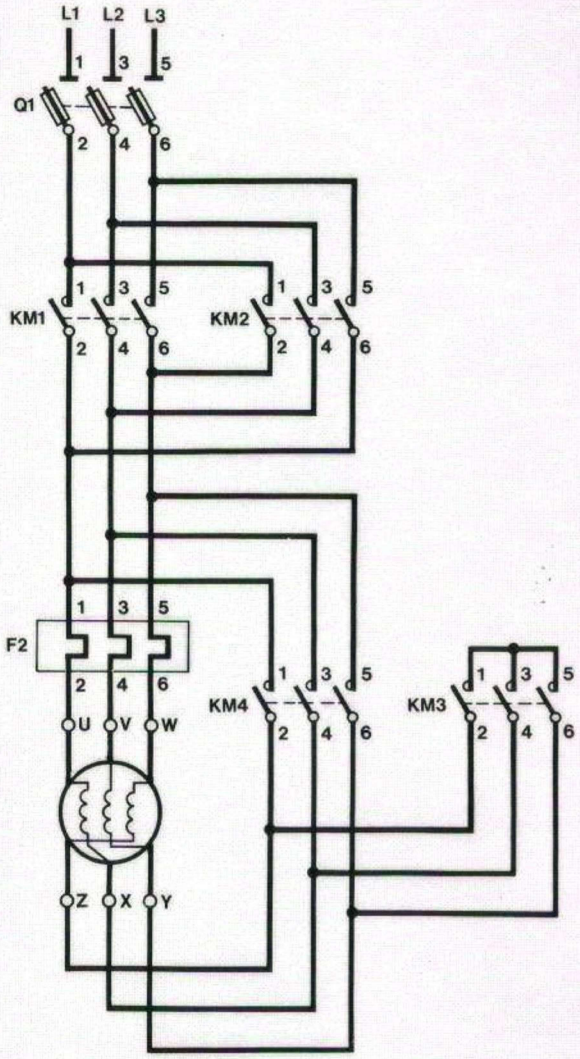
(schematics A and B).
Motor In in delta (schematic C).

CONTROL CIRCUIT OPERATION
(schematic D)

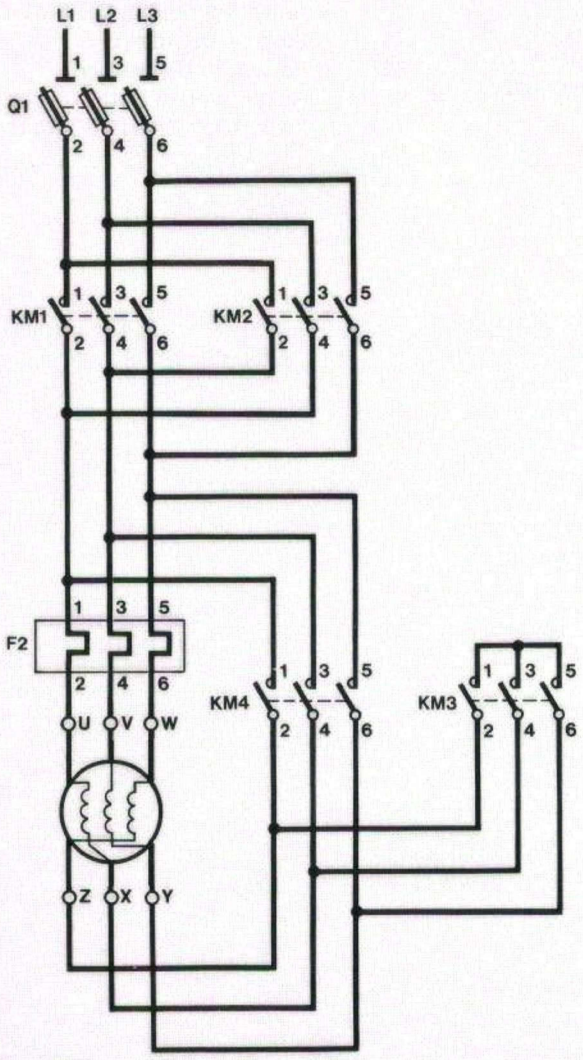
Operate S2 or S3.
Closing of KM1 or KM2.
Hold in of KM1 or KM2 (13-14).
Closing of KM3 by KM1 or KM2 (53-54).
Closing of KA1 by KM3 (13-14).
Hold in of KA1 (13-14).
Opening of KM3 by KA1 (55-56).
Closing of KM4 by KM2 (31-32).
Stop: by operating S1.

- **Features**

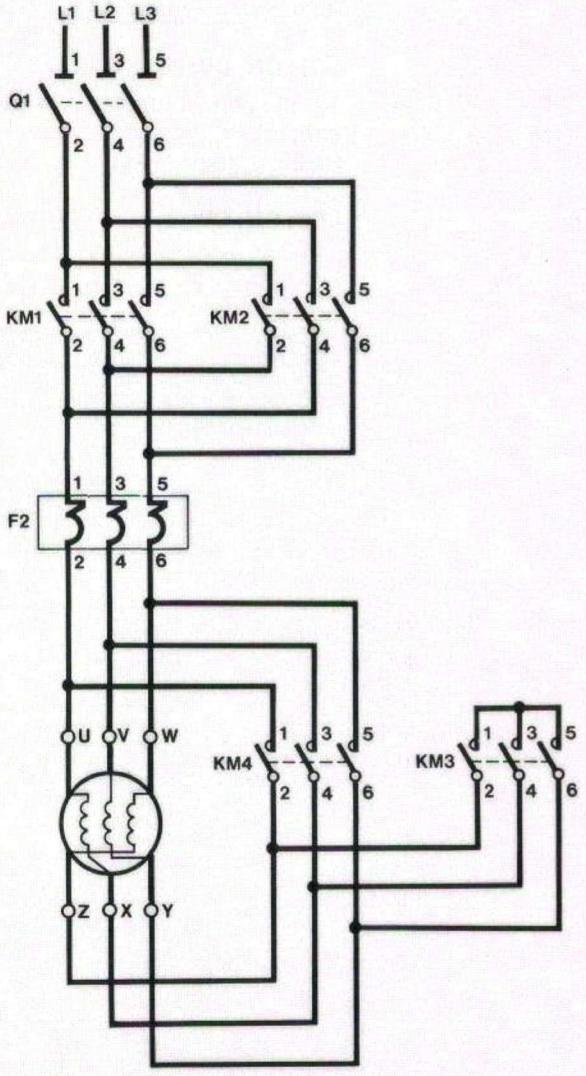
Mechanical and electrical interlock between KM1 and KM2.
Electrical interlock between KM3 and KM4.



Schematic A



Schematic B



Schematic C

REQUIRED EQUIPMENT

Q1: 1 triple pole isolator (optional). Rating: Motor In in delta.
LS1-D or **DK1.**
3 fuses (optional) - Rating: Motor In in delta.

KM1 + KM2: 1 pair of triple pole contactors with 1 N/C and 1 N/O auxiliary contacts.
Rating: Motor In in Δ.
LC2-D; NC2 or 2 contactors **CV** or **LC1** mechanically interlocked.

KM3: 1 triple pole contactor with 1 N/C and 1 N/O auxiliary contacts.
Rating: $\frac{\text{Motor In in } \Delta}{3}$
LC1; CN; CV;

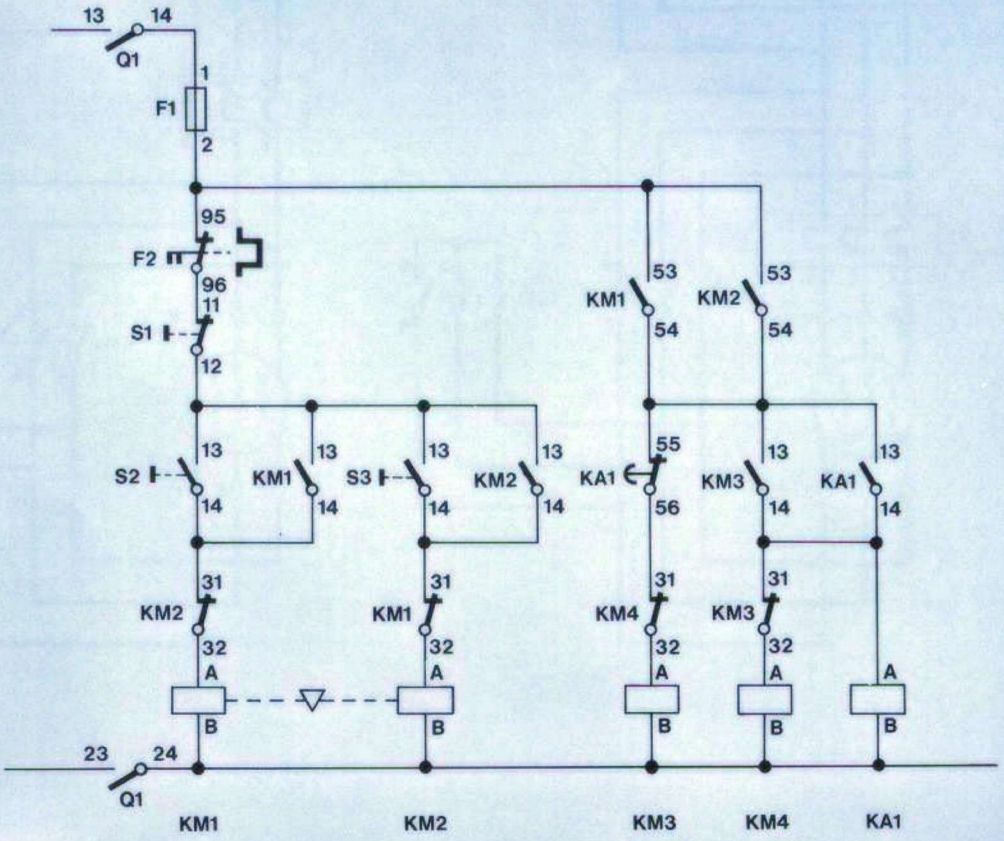
KM4: 1 triple pole contactor with 1 N/C auxiliary contact.
Rating: $\frac{\text{Motor In in } \Delta}{\sqrt{3}}$
LC1; CN; CV.
Mechanical interlocking is recommended between **KM3** and **KM2.**
In this case use **LC2-D** or **NC2.**

KA1: 1 control relay with time delay on energization.
CA2-AN + CA2-AS22; CA2-DN + LA2-D22; CA2-FT.
Approximate time delay 7 to 15 sec.

F2: In series with the motor windings.
1 thermal overload relay.
Rating: $\frac{\text{Motor In in } \Delta}{\sqrt{3}}$ (schematics A and B).
LR1 or **RA1** or a thermal magnetic overload relay (schematic C): **RMT-D.**

S1: Stop push button.
S2: Forward push button.
S3: Reverse push button.
XAB; XAF; XAG; XB2-M, etc.

* see page 105



Schematic D

Star delta resistance starter

POWER CIRCUIT OPERATION (schematics A and C)

Manual closing of Q1.
Closing of KM1 - star connection.
Closing of KM2 - line connection.
Opening of KM1 - opening of star connection.
Closing of KM3 - delta connection with resistance.
Closing of KM11 - opening of resistance.

- **Features**

Motor with 6 output terminals.
The voltage permissible across the windings connected in delta should correspond to the main supply voltage.

REQUIRED EQUIPMENT

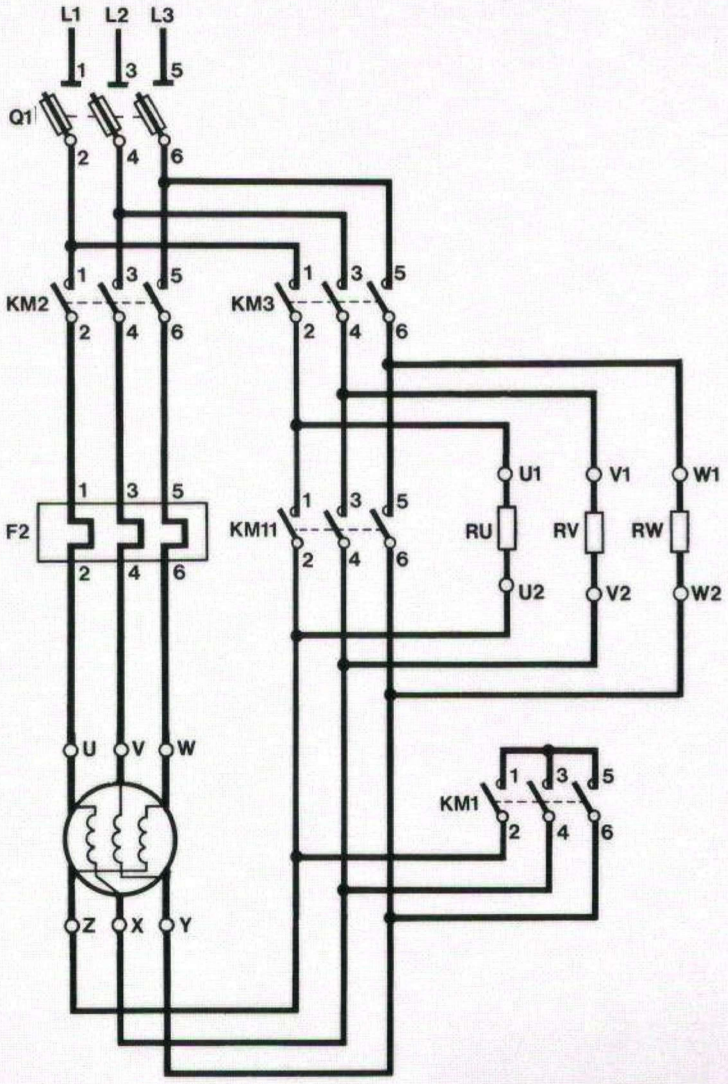
Q1 - Rating: Motor In in delta.

KM1 - Rating: $\frac{\text{Motor In in } \Delta}{3}$

KM2 and **KM3** - Rating: $\frac{\text{Motor In in } \Delta}{\sqrt{3}}$

KM11 - Rating: $\frac{\text{Motor In in } \Delta}{\sqrt{3}}$

F2 - Rating: $\frac{\text{Motor In in } \Delta}{\sqrt{3}}$



Schematic A

CONTROL CIRCUIT OPERATION
(schematic B)

Operate S2.
Closing of KM1.
Closing of KM2 by KM1 (13-14) and energization of overload relay F3.
Hold in of KM2 (13-14).
Opening of KM1 by KM2 (55-56).
Closing of KM3 by KM1 (31-32).
Closing of KM11 by KM3 (67-68).
Opening of supply to F3 by KM11 (31-32).
Stop: by operating S1.

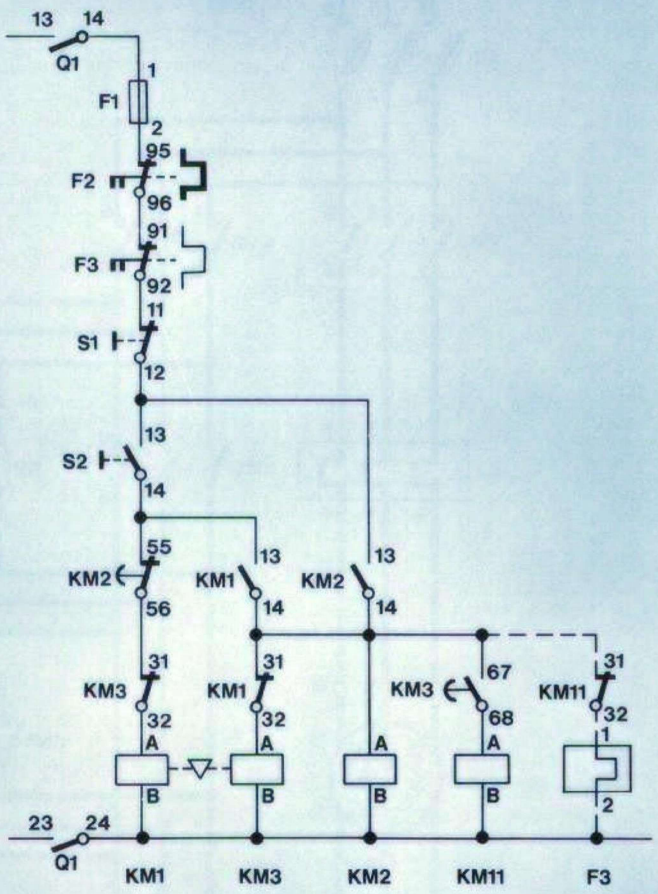
- **Features**

Electrical interlock between KM1 and KM3.
Mechanical interlocking recommended.
F3 - Thermal overload relay protecting the resistance against too frequent starting.

CONTROL CIRCUIT OPERATION
(schematic D)

Operate S2.
Closing of KM1.
Closing of KM2 and KA1 by KM1 (13-14).
Hold in of KM2 (13-14) and KA1 (13-14) and energization of overload relay F3.
Opening of KM1 by KA1 (55-56).
Closing of KM3 by KM1 (31-32).
Closing of KA2 by KM3 (13-14).
Closing of KM11 by KA2 (67-68).
Opening of supply to F3 by KM11 (31-32).
Stop: by operating S1.

* see page 105



Schematic B

• **Features**
Electrical interlock between KM1 and KM3.
Mechanical interlocking recommended.
F3 - Thermal overload relay protecting the resistance against too frequent starting.

REQUIRED EQUIPMENT

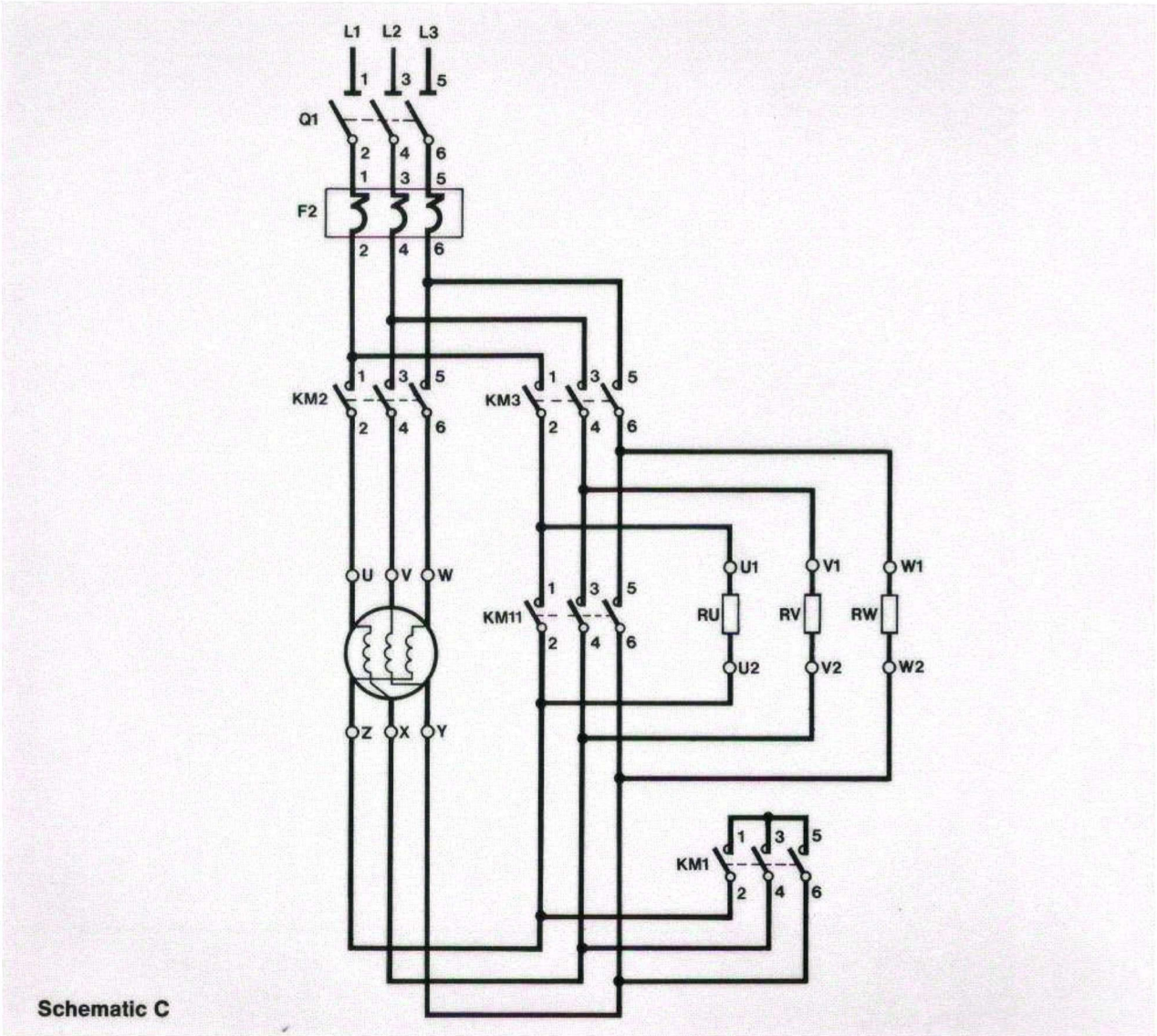
Q1: 1 triple pole isolator (optional). Rating: Motor In in delta: **DK1,** etc.
3 main fuses (optional). Rating: Motor In in Δ

KM1: 1 triple pole contactor with 1 N/C and N/O auxiliary contacts.
Rating: $\frac{\text{Motor In in } \Delta}{3}$
LC1; CN or **CV.**

KM2: 1 triple pole contactor with 1 N/O auxiliary contact and time delay block or separate timing relay.
Rating: $\frac{\text{Motor In in } \Delta}{\sqrt{3}}$
LC1-D; CN or **CV.**
If a LC1-F or CN, use control relay with time delay on energization (KA1 on schematic D).

KM3: 1 triple pole contactor with 1 N/C auxiliary contact and time delay block or separate timing delay.
Rating: $\frac{\text{Motor In in } \Delta}{\sqrt{3}}$
LC1-D; CN or **CV.**
If a LC1-F or CN, use control relay with time delay on energization (KA2 on schematic D) and provide an additional N/O contact on KM3.

KM11: 1 triple pole contactor with 1 N/C auxiliary contact.



Schematic C

Rating: $\frac{\text{Motor In in } \Delta}{\sqrt{3}}$

LC1; CN or **CV.**
Mechanical interlock between KM1 and KM3 recommended.

KA1 + 2 control relays with time delay on
KA2: energization (only if KM2 and KM3 are LC1-F or CN) **CA2-AN + CA2-AS22; CA2-DN + LA2-D22; CA2-FT.**
Usual time delays, KA1: 15 sec.; KA2: 3 sec.

F2: In series with motor windings (schematic A).
1 thermal overload relay.
Rating: $\frac{\text{Motor In in } \Delta}{\sqrt{3}}$

LR1; RA1 or
in series with supply line (schematic C).

1 thermal magnetic overload relay.
Rating: Motor In in delta.
RMT-D.

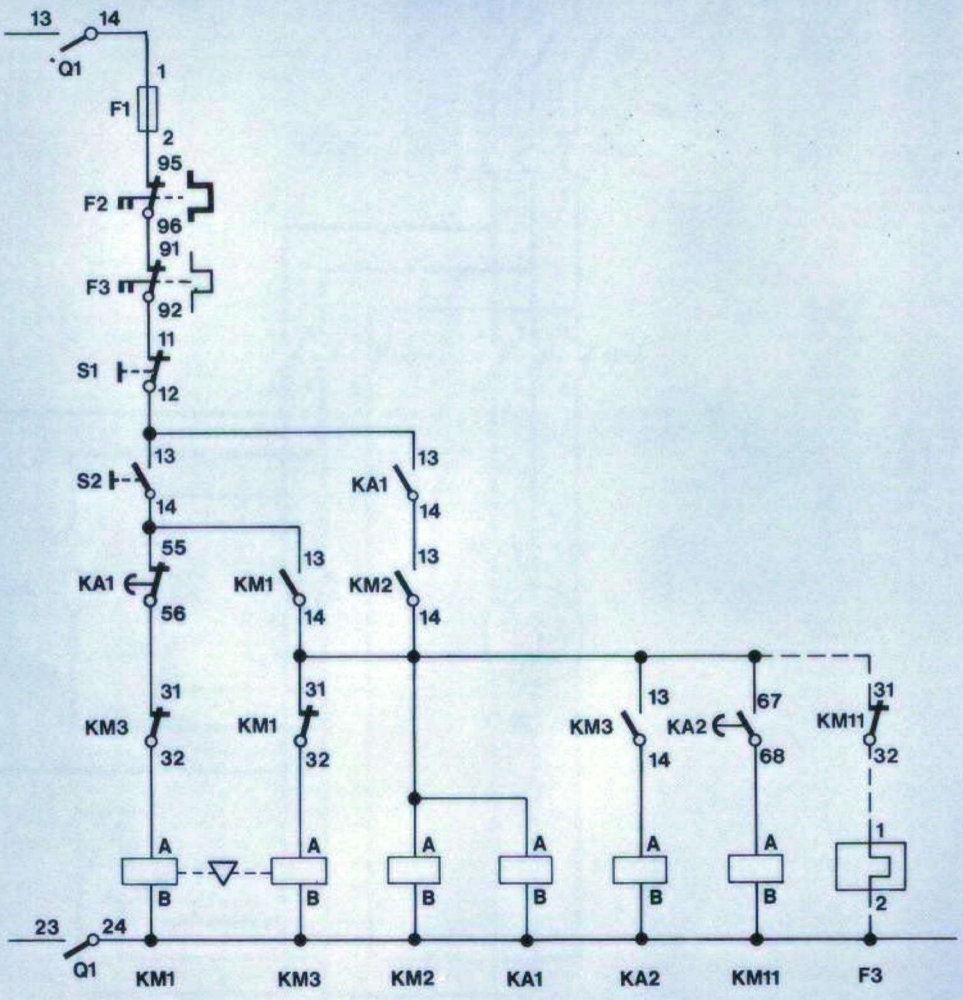
F3: 1 thermal time delay relay - For protection of starting resistance.
RT1-TK (optional).

RU + RV + RW: Starting resistances - Values depend on motor power.

S1: Stop push button.

S2: Start push button.
XAB; XAF; XAG; XBF or **XB2,** etc.

* see page 105



Schematic D

Primary resistance starter

POWER CIRCUIT OPERATION
(schematic A)

Manual closing of Q1.
Closing of KM11 - Motor energised with resistances inserted.
Closing of KM1 - Shorting of resistances.
Direct connection of motor to the line.

- **Features**

Q1 - Rating: Motor In.
KM11 - Rating: $\frac{\text{Motor In}}{2}$

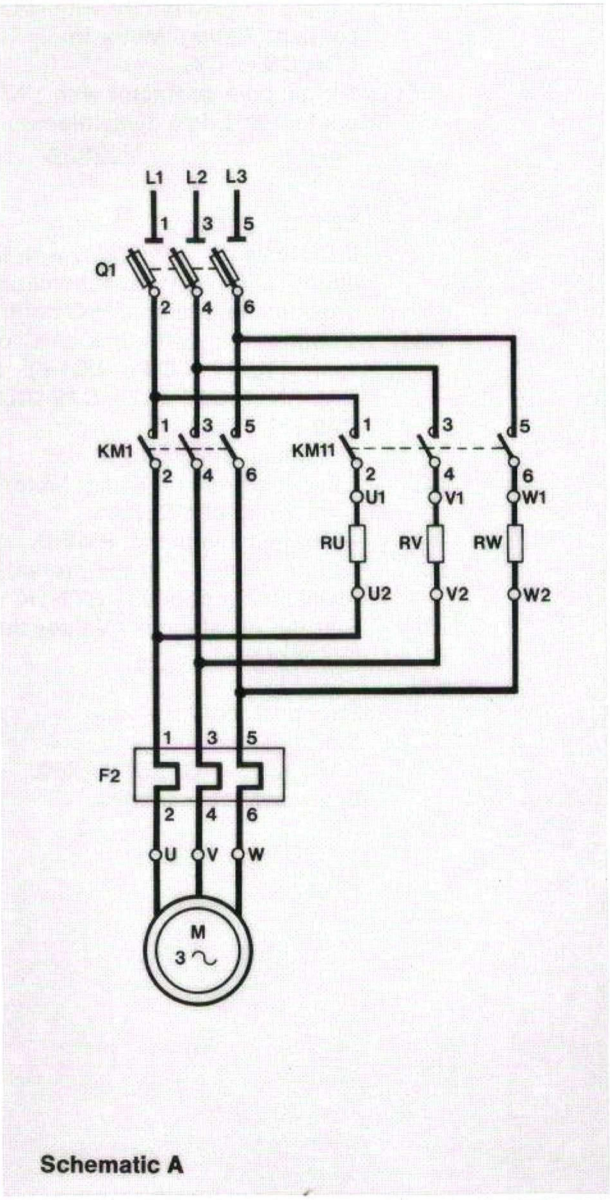
KM1 : Rating: Motor In.
F2 - Rating: Motor In.

CONTROL CIRCUIT OPERATION
(schematic B)

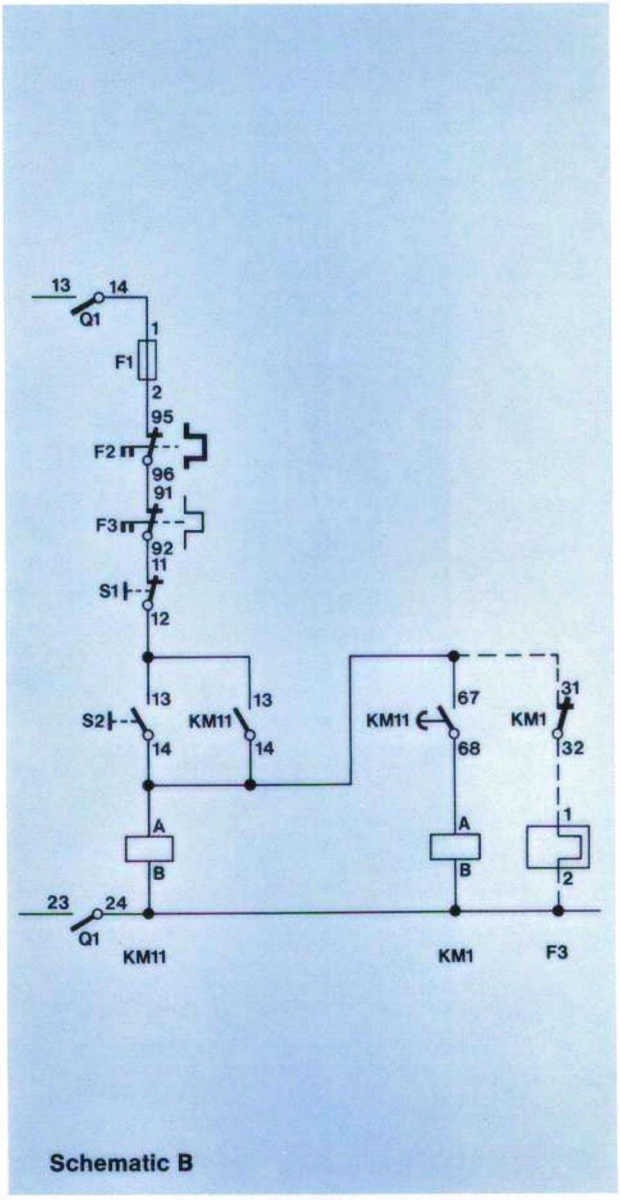
Operate S2.
Closing of KM11.
Hold in of KM11 (13-14) and energization of overload relay F3.
Closing of KM1 by KM11 (67-68).
De-energization of F3 by KM1 (31-32).
Stop: by operating S1.

- **Feature**

F3 - Thermal overload relay protecting the resistance against too frequent starting.



Schematic A



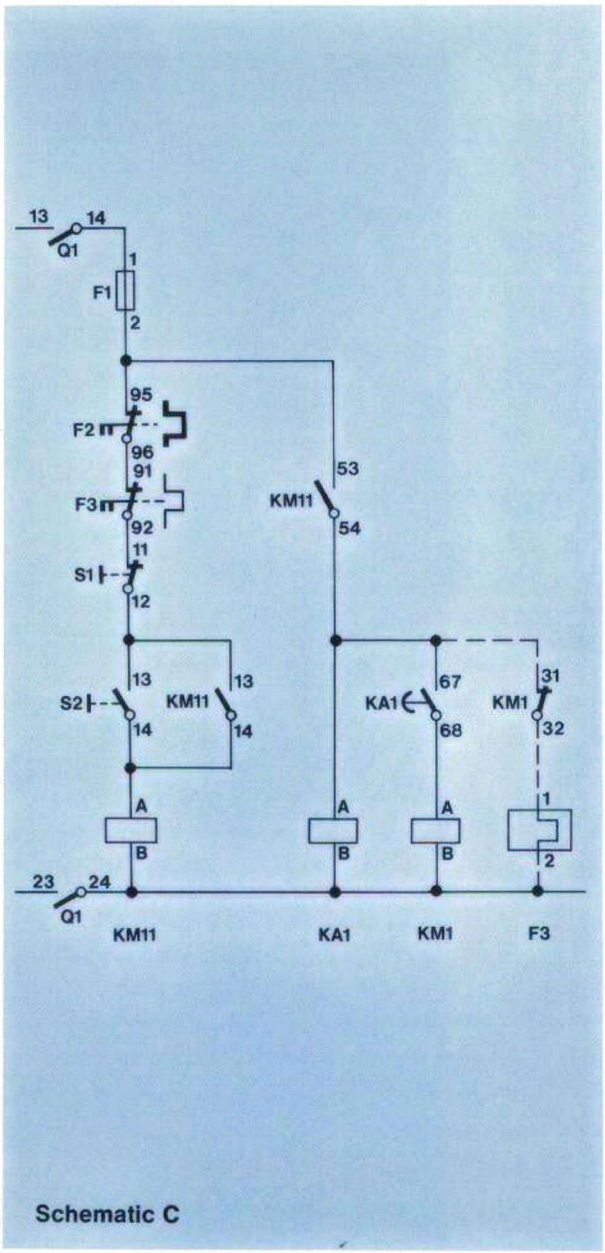
Schematic B

CONTROL CIRCUIT OPERATION (schematic C)

Operate S2.
Closing of KM11.
Hold in of KM11 (13-14).
Closing of KA1 by KM11 (53-54) and energization of overload relay F3.
Closing of KM1 by KA1 (67-68).
De-energization of F3 by KM1 (31-32).
Stop: by operating S1.

- **Feature**

F3 - Thermal overload relay protecting the resistances against too frequent starting.



Schematic C

REFERENCES OF AVAILABLE EQUIPMENT

- **Open Type starters**

With or without isolator. With thermal overload relay. With starting resistance.
Without relay F3.
LC5-D; NS1.

- **Enclosed equipment**

With or without isolator. With thermal overload relay. With starting resistance.
Without relay F3.
LE5-D; NS1.

REQUIRED EQUIPMENT

Q1: 1 triple pole isolator (optional).
Rating: Motor In.: **DK1.**
3 main fuses (optional). Rating: Motor In.

KM1: 1 triple pole contactor with N/O auxiliary contact. Rating: Motor In.
LC1; CN or **CV.**

KM11: 1 triple pole contactor with 1 N/O auxiliary contact and time delay block.
Rating: $\frac{\text{Motor In}}{2}$

LC1; CN or **CV.**
If **CN1** use a control relay with time delay on energization (KA1 on schematic C) and provide an additional N/O contact.

KA1: 1 control relay with time delay on energization (only if **KM11** is **CN** or **LC1-F)**
CA2-AN + CA2-AS22; CA2-DN + LA2-D22 or **CA2-FT.**
Usual time delay 7 to 15 sec.

F2: 1 overload relay. Rating: Motor In:
— thermal: **LR1-D; RA1;**
— thermal magnetic: **RMT-D.**

F3: 1 thermal relay - for the protection of starting resistance (optional) - **RT1-TK.**

RU+
RV+
RW: Starting resistances - Values depend on motor power.

S1: Stop push button.

S2: Start push button
XAB; XAF; XAG; XBF or **XB2.**
Equipment accessories.

POWER CIRCUIT OPERATION
(schematic D)

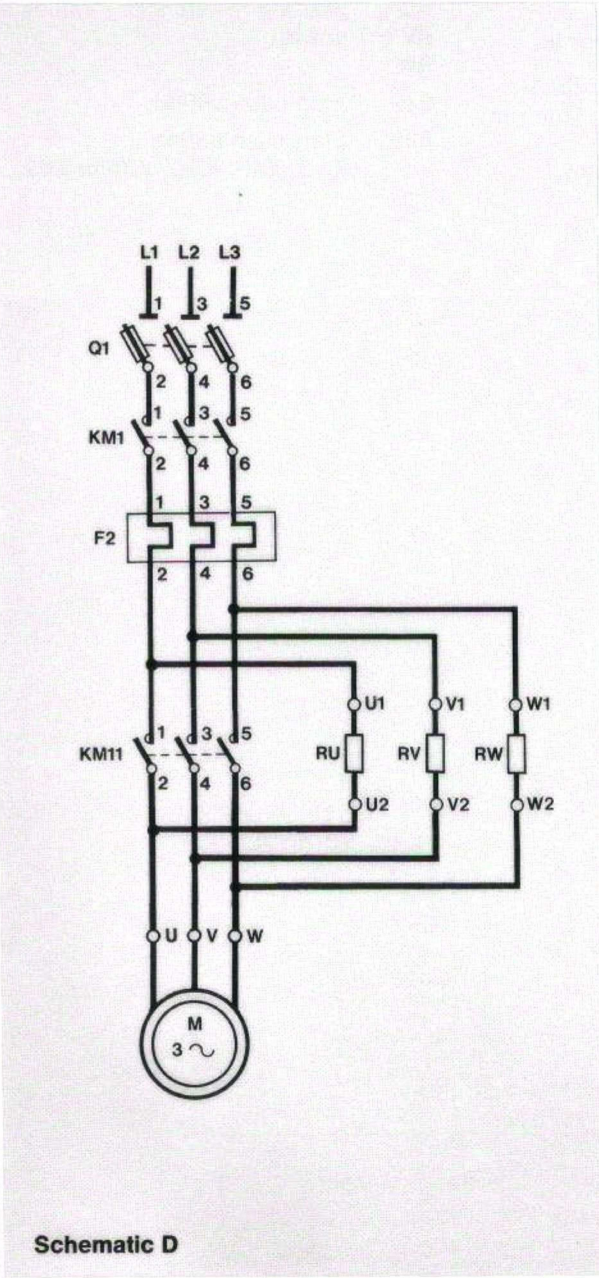
Manual closing of Q1.
Closing of KM1 - Motor energized with resistances inserted.
Closing of KM11 - Shorting of resistances.
Direct connection of the motor to the line.

- **Features**

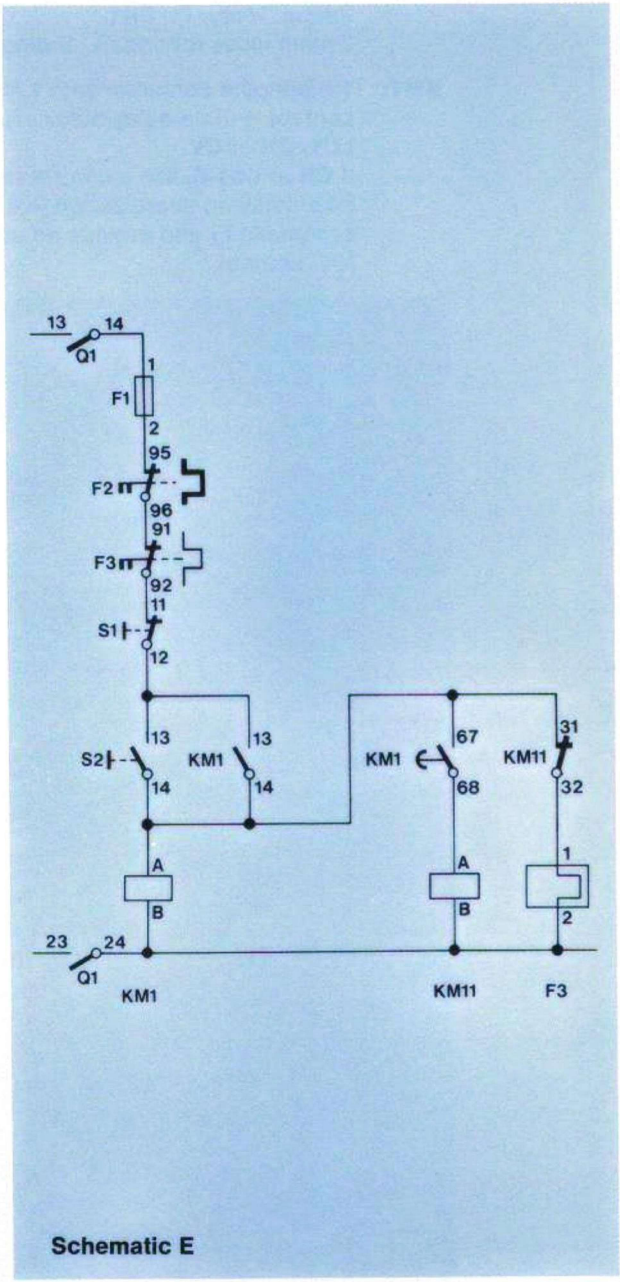
Q1 - Rating: Motor In.
KM1-KM11 - Rating: Motor In.
F2 - Rating: Motor In.

CONTROL CIRCUIT OPERATION
(schematic E)

Operate S2.
Closing of KM1.
Hold in of KM1 (13-14) and energization of overload relay F3.
Closing of KM11 by KM1 (67-68).
De-energization of F3 by KM11 (31-32).
Stop: by operating S1.



Schematic D



Schematic E

CONTROL CIRCUIT OPERATION (schematic F)

Operate S2.
Closing of KM1.
Hold in of KM1 (13-14).
Closing of KA1 by KM1 (53-54) and energization of overload relay F3.
Closing of KM11 by KA1 (67-68).
De-energization of F3 by KM11 (31-32).
Stop: by operating S1.

REQUIRED EQUIPMENT

Q1: 1 triple pole isolator (optional). Rating: Motor In: **DK1.**
3 main fuses (optional). Rating: Motor In.

KM1: 1 triple pole contactor with 1 N/O auxiliary contact + time delay block. Rating: Motor In. **LC1; CN** or **CV.**
If **CN** or **LC1-F,** use a control relay with time delay on energization (KA1 on schematic F) and provide an additional N/O contact.

KM11: 1 triple pole contactor + N/C auxiliary contact. Rating: Motor In. **LC1; CN** or **CV.**

KA1: 1 control relay with time delay on energization (only if KM1 is CN or LC1-F). **CA2-AN + CA2-AS22; CA2-DN + LA2-D22, CA2-FT.**
Usual time delay 7 to 15 sec.

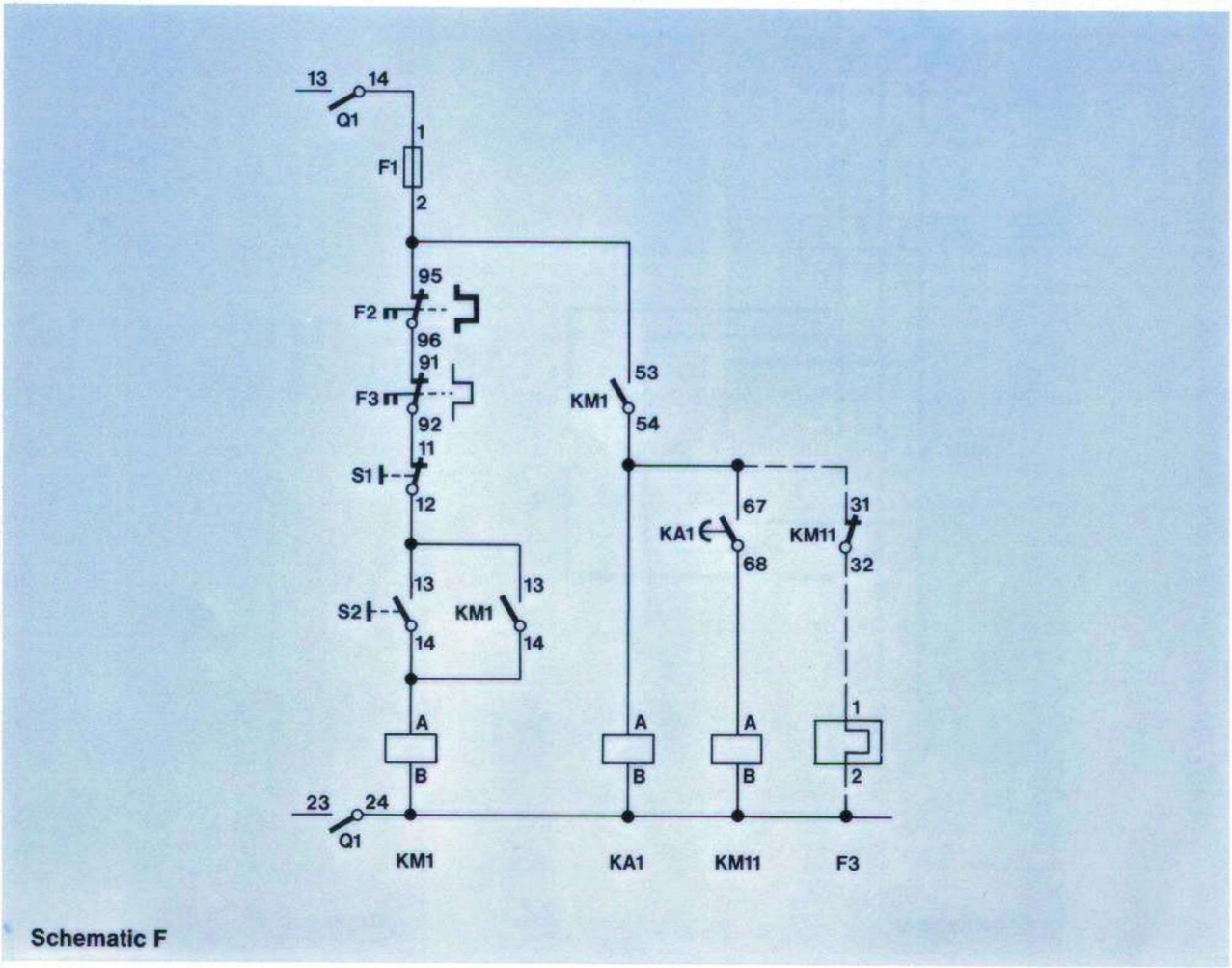
F2: 1 overload relay. Rating: Motor In:
— thermal: **LR1-D; RA1;**

F3: — thermal relay - for protection of starting resistance (optional) **RT1-TK.**
Usual time delay: 2 to 3 consecutive starts.

RU+ RV+ RW: Starting resistances - Values depend on motor power.

S1: Stop push button.

S2: Start push button **XAB; XAF; XAG; XBF** or **XB2.**



Schematic F

Primary Resistance Reversing Starter

POWER CIRCUIT OPERATION
(schematics A and B)

Manual closing of Q1.
Closing of KM1 or KM2 - Motor energization with resistances inserted.
Closing of KM11 - Shorting of resistances. Direct connection of the motor to the lines.

- **Features**

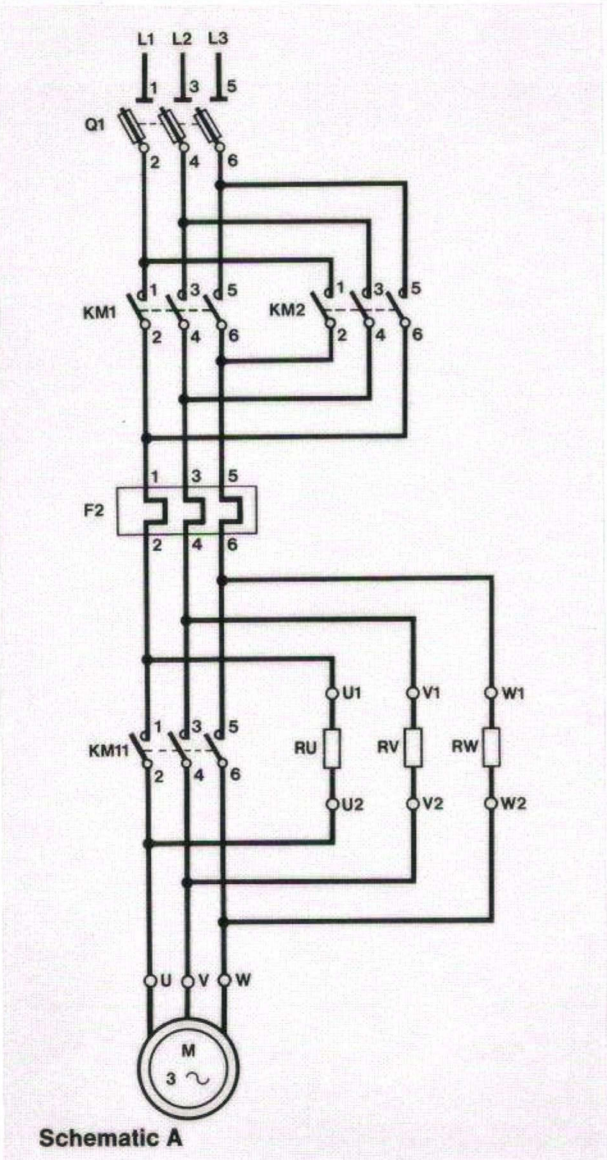
Q1 - Rating: Motor In.
KM1-KM2 - Rating: Motor In.
KM11 - Rating: Motor In.
F2 - Rating: Motor In.

CONTROL CIRCUIT OPERATION
(schematic C)

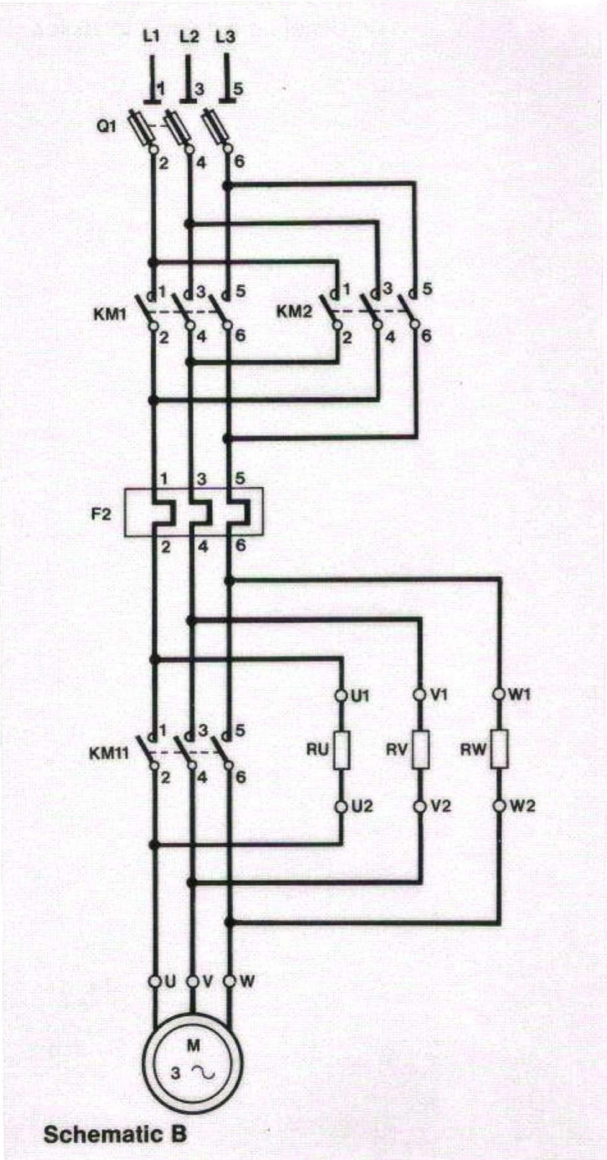
Operate S2 or S3.
Closing of KM1 or KM2.
Interlocking of KM2 or KM1 (31-32).
Hold in of KM1 or KM2 (13-14).
Closing of KA1 by KM1 or KM2 (53-54) and energization of overload relay F3.
De-energization of F3 by KM11 (31-32).
Stop: operating S1.

- **Features**

Mechanical and electrical interlock between KM1 and KM2.
F3 - Thermal overload relay protecting the resistances against too frequent starting.



Schematic A



Schematic B

REQUIRED EQUIPMENT

Q1: 1 triple pole isolator (optional).
Rating: Motor In: **DK1.**
3 main fuses (optional). Rating: Motor In.

KM1+ KM2: 1 pair of mechanically interlocked contactors each having:
3 main poles and 1 N/C + 2 N/O auxiliary contacts. Rating: Motor In.
LC2 or **NC2** or two contactors **LC1** or **CV** with mechanical interlock

KM11: 1 triple pole contactor + 1 N/C auxiliary contact. Rating: Motor In.
LC1 ; CN or **CV.**

KA1: 1 control relay with time delay on energization.
CA2-AN + CA2-AS22; CA2-DN + LA2-D22 or **CA2-FT.**
Usual time delay 7 to 15 sec.

F2: 1 overload relay. Rating: Motor In:
— thermal: **LR1** or **RA1;**

F3: — thermal relay - for protection of starting resistances.
RT1-TK (optional).
Usual time delay: 2 to 3 consecutive starts.

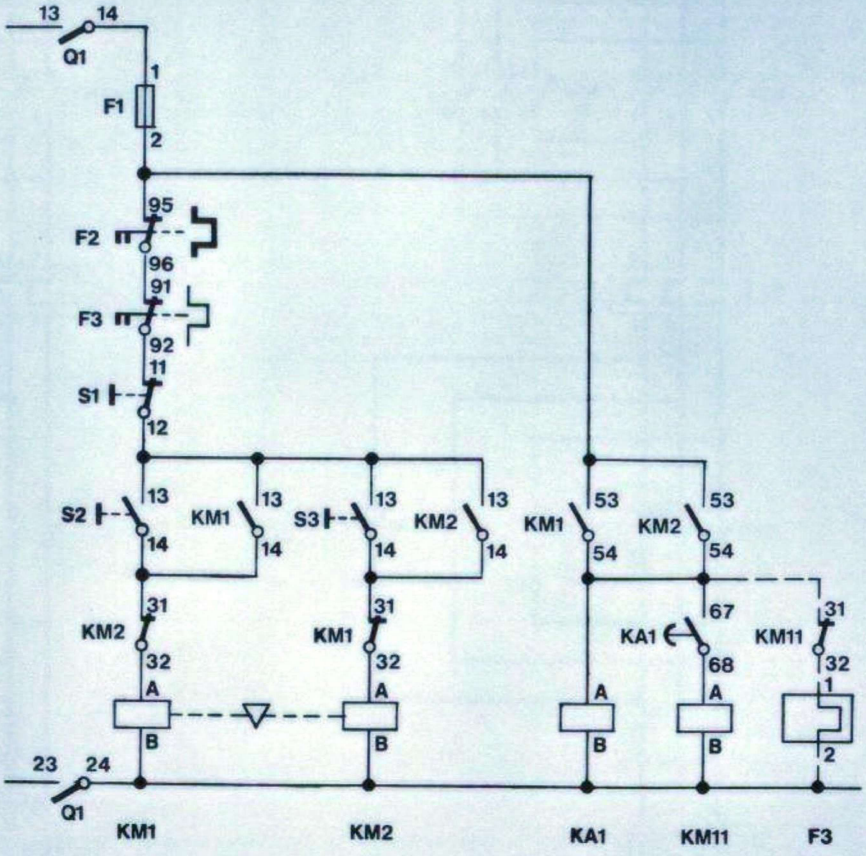
RU+ RV+ RW: Starting resistance - Values depend upon the motor power.

S1: Stop push button.

S2: Forward push button.

S3: Reverse push button
XAB; XAF; XAG; XBF or **XB2.**

* see page 105



Schematic C

Autotransformer starter

POWER CIRCUIT OPERATION

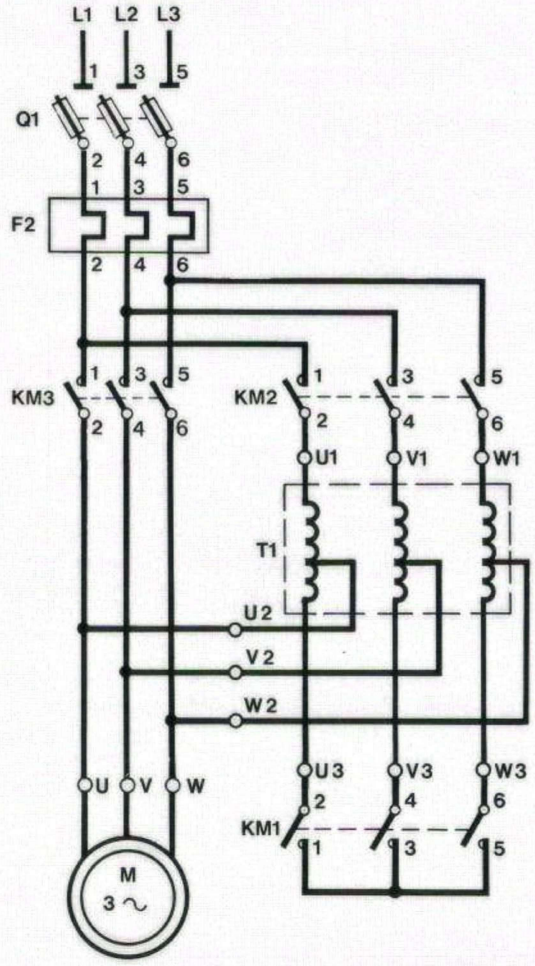
Manual closing of Q1.
Closing of KM1 - Star connection of autotransformer.
Closing of KM2 - Starting of motor.
Opening of KM1 - Opening of autotransformer star connection.
Closing of KM3 - Motor connected directly to the supply.
Opening of KM2 - Disconnection of autotransformer.

- **Features**

Q1 - Rating: Motor In
KM1 + - Rating: Motor In
KM2 +
KM3
F2 - Rating: Motor In

CONTROL CIRCUIT OPERATION

Operate S2.
Closing of KM1.
Interlocking of KM3 by KM1 (31-32).
Closing of KA1 by KM1 (13-14) and energization of overload relay F3.
Closing of KM2 by KA1 (13-14).
Hold in of KM2 (13-14).
Opening of KM1 by KA1 (55-56).
Closing of KM3 by KM1 (31-32).
Interlocking of KM1 by KM3 (31-32).
Hold in of KM3 (13-14).
Opening of KA1 by KM3 (61-62).
De-energization of F3 by KM3 (61-62).
Opening of KM2 by KA1 (13-14).
Stop: by operating S1.



• Features

F3 - Thermal relay protecting the autotransformer against too frequent starting.

REQUIRED EQUIPMENT

Q1: 1 triple pole isolator (optional).
Rating: Motor In: **DK1.**
3 main fuses. Rating: Motor In.

KM1: 1 triple pole contactor + 1 N/C + 1 N/O auxiliary contacts. Rating: Motor In.
LC1; CN or **CV.**

KM2: 1 triple pole contactor + 1 N/O auxiliary contact. Rating: Motor In.
LC1; CN or **CV.**

KM3: 1 triple pole contactor + 2 N/C + 1 N/O auxiliary contacts. Rating: Motor In.
LC1; CN or **CV.**

KA1: 1 control relay with time delay on energization.
CA2-AN + CA2-AS22; CA2DN + LA2-D22; CA2-FT.
Usual time delay 5 to 10 sec.

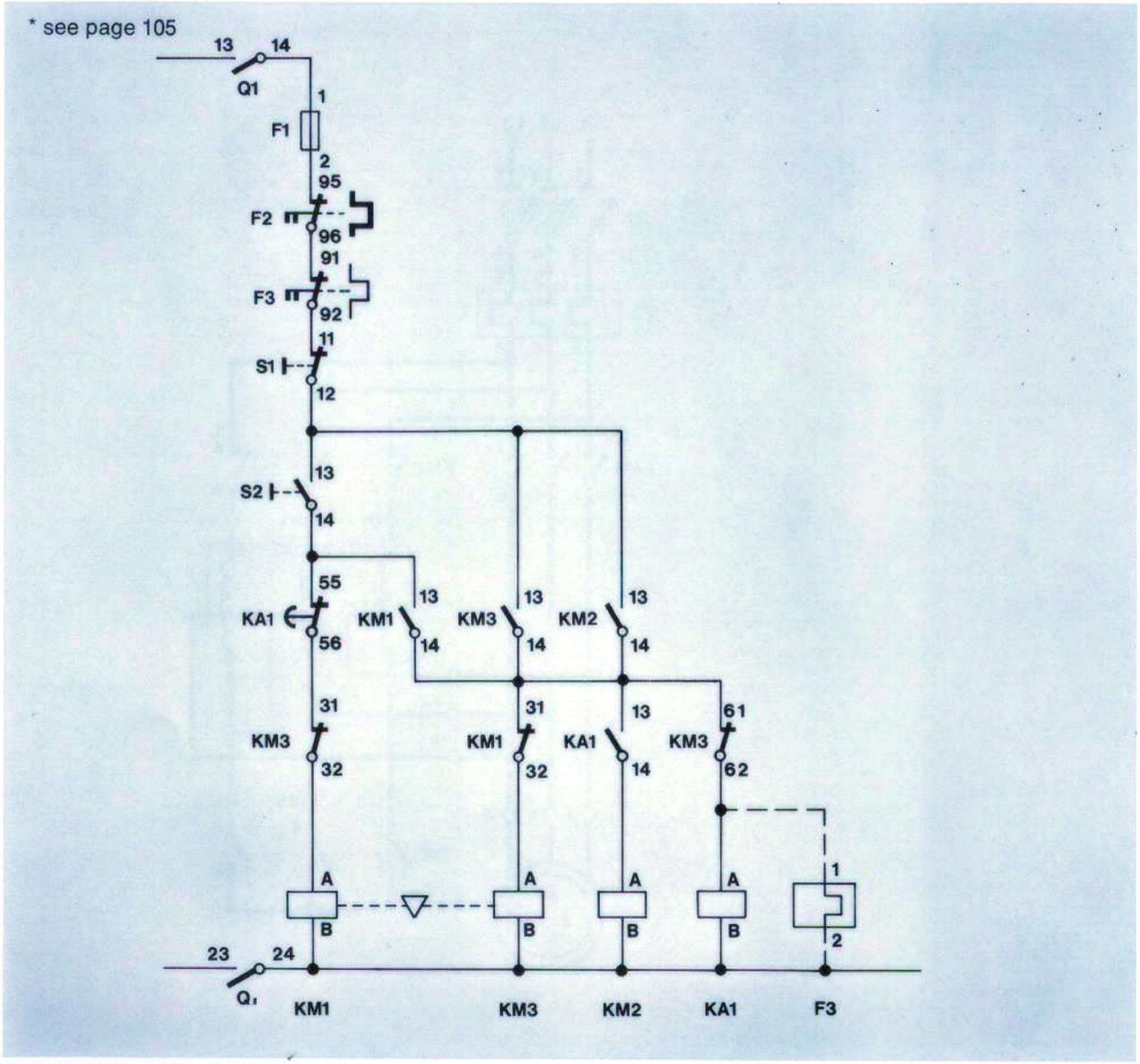
F2: 1 overload relay. Rating: Motor In.:
— thermal: **LR1** or **RA1;**
— thermal magnetic: **RMT-D.**

F3: 1 thermal relay - for autotransformer protection **RT1-K.**
Usual time delay: 2 to 3 consecutive starts.

S1: Stop push button.

S2: Start push button
XAB; XAF; XAG; XBF or **XB2.**
Equipment accessories.

* see page 105



2 speed starter - with separate windings
(schematic A)

POWER CIRCUIT OPERATION

Manual closing of Q1.
Closing of KM1 or KM2.

- **Features**

Q1 - Rating: for highest In.
KM1 - Rating: Motor In low speed.
KM2 - Rating: Motor In high speed.
Electrical and mechanical interlock between KM1 and KM2.
To achieve this mechanical interlocking it is sometimes necessary to use contactors of identical size.
F2 - Rating: Motor In low speed.
F3 - Rating: Motor In high speed.

CONTROL CIRCUIT OPERATION
(schematic B)

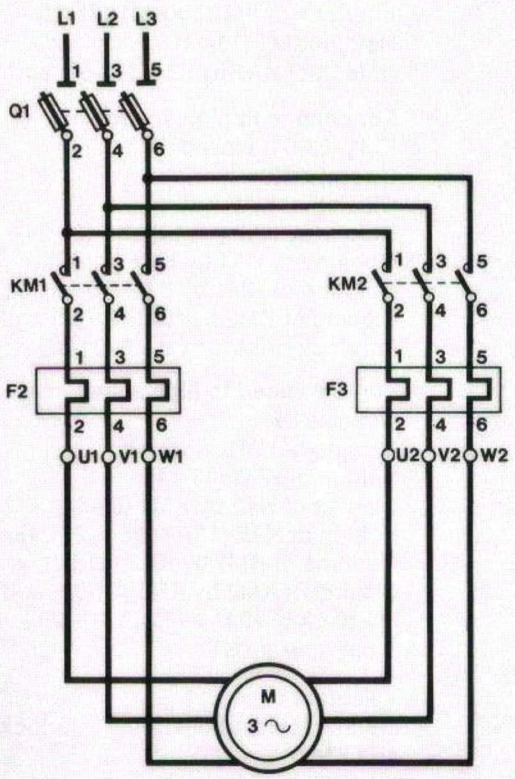
Operate S2.
Closing of KM1.
Interlock of KM2 by KM1 (31-32).
Hold in of KM1 (13-14)

or

Operate S3.
Closing of KM2.
Interlock if KM1 by KM2 (31-32).
Hold in of KM2 (13-14).
Stop: by operating S1.

- **Features**

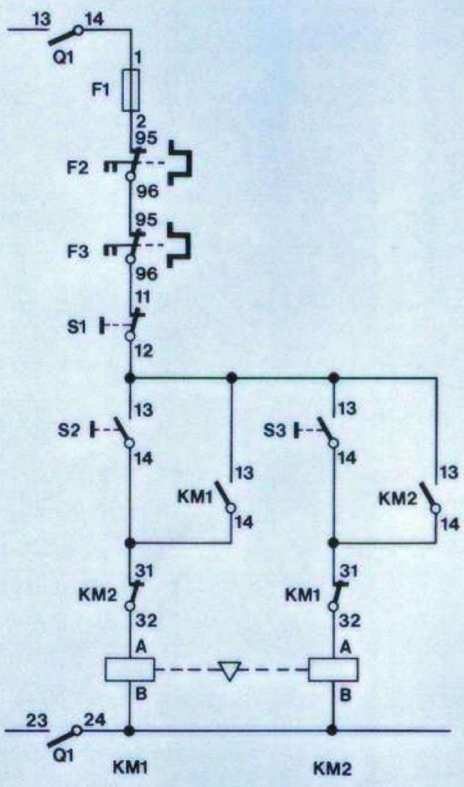
Electrical and mechanical interlock between KM1 and KM2.



Schematic A

* see page 105

— Change from low speed to high speed or vice versa after stopping.



Schematic B

CONTROL CIRCUIT OPERATION
(schematic C)

Operate S2.
Closing of KM1.
Interlock of KM2 by KM1 (31-32).
Hold in of KM1 (13-14)

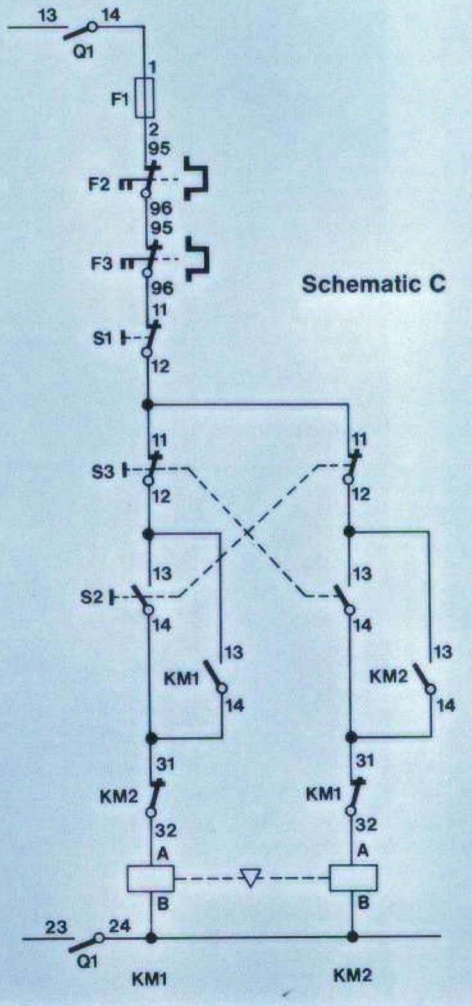
or
Operate S3.
Closing of KM2.
Interlock of KM1 by KM2 (31-32).
Hold in of KM2 (13-14).
Stop: by operating S1.

- **Features**

Mechanical and electrical interlock between KM1 and KM2.
Start push buttons include N/O and N/C contacts.

* see page 105

— Change from low speed to high speed or vice versa after stopping.



Schematic C

CONTROL CIRCUIT OPERATION
(schematic D)

Operate S2.
Closing of KM1.
Interlock of KM2 by KM1 (31-32).
Hold in of KM1 (13-14).

Change to high speed:
KM1 (67-68) closed:
Operate S3.
Closing of KA1.
Hold in of KA1 (13-14).
Opening of KM1 by KA1 (31-32).
Closing of KM2 by KM1 (23-24) and KM1 (31-32).
Interlock of KM1 by KM2 (31-32).
Hold in of KM2 (13-14).
Stop: operate S1.

- **Features**

Mechanical and electrical interlock between KM1 and KM2.

CONTROL CIRCUIT OPERATION
(schematic E)

Operate S2.
Closing of KA1.
Closing of KM1 by KA1 (23-24).
Interlock of KM2 by KM1 (31-32).
Hold in KM1 (13-14).
Hold in of KA1 by KM1 (53-54) and KA1 (13-14).

For change to high speed:
KM1 (63-64) closed:
Operate S3.
Closing of KA2.
Hold in of KA2 (13-14) and (23-24).
Opening of KA1 by KA2 (41-42).
Opening of KM1 by KA2 (55-56).
Closing of KM2 by KM1 (31-32) and KA2 (67-68).
Interlock of KM1 by KM2 (31-32).

For low speed to high speed in automatic:
Operate S3.
Closing of KM1.
Hold in of KM1 (13-14).
Closing of KA2 by KM1 (63-64).
Hold in of KA2 (13-14) and (23-24).
Opening of KM1 by KA2 (55-56).
Closing of KM2 by KM1 (31-32) and KA2 (67-68).
Interlock of KM1 by KM2 (31-32).
Stop: operate S1.

- **Features**

Mechanical and electrical interlock between KM1 and KM2.

CONTROL CIRCUIT OPERATION (schematic F)

For low speed:
Operate S2.
Closing of KA1.
Closing of KM1 by KA1 (23-24).
Interlock of KM2 by KM1 (31-32).
Hold in of KM1 (13-14).
Hold in of KA1 by KM1 (53-54) and KA1 (13-14).

For change to high speed:
Operate S3.
Closing of KA2.
Opening of KA1 by KA2 (41-42).
Hold in KA2 (13-14) and (23-24).
Opening of KM1 by KA2 (55-56).
Closing of KM2 by KM1 (31-32) and KA2 (67-68).
Interlock of KM1 by KM2 (31-32).

For low speed to high speed in automatic:
Operate S3.
Closing of KM1.
Interlock of KM2 by KM1 (31-32).
Hold in of KM1 (13-14).
Closing of KA2 by KM1 (63-64).
Hold in of KA2 (13-14) and (23-24).
Opening of KM1 by KM2 (55-56).
Closing of KM2 by KA2 (67-68) and KM1 (31-32).
Interlock of KM1 by KM2 (31-32).

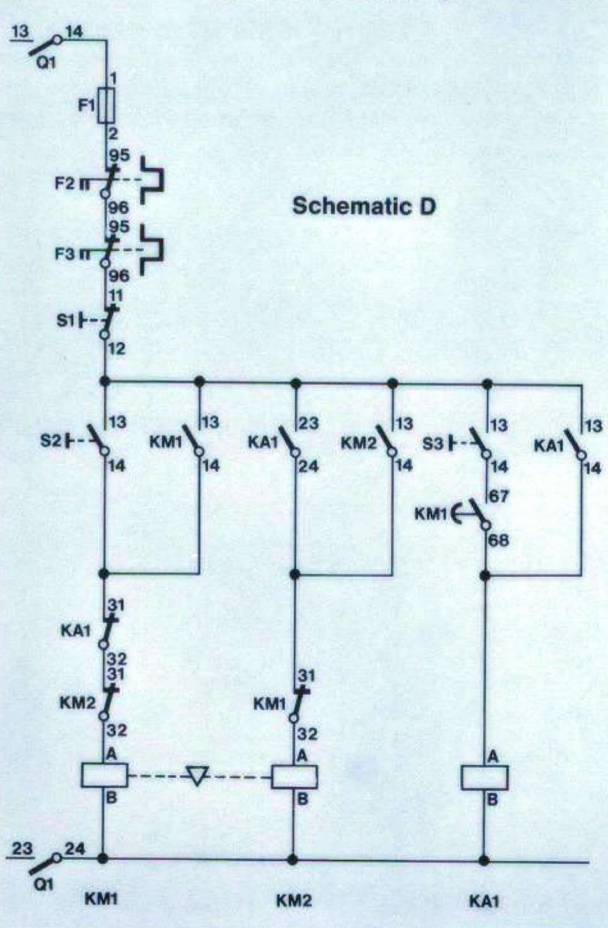
For change from high speed to low speed:
Operate S2.
Closing of KA1.
Opening of KA2 by KA1 (41-42).
Opening of KM2 by KA2 (67-68).
Closing of KM1 by KM2 (31-32), KA1 (23-24) and KA2 (55-56).
Hold in of KA1 by KM1 (53-54).
Interlock of KM2 by KM1 (31-32).
Stop: operate S1.

• **Features**
Mechanical and electrical interlock between KM1 and KM2.

* see page 105

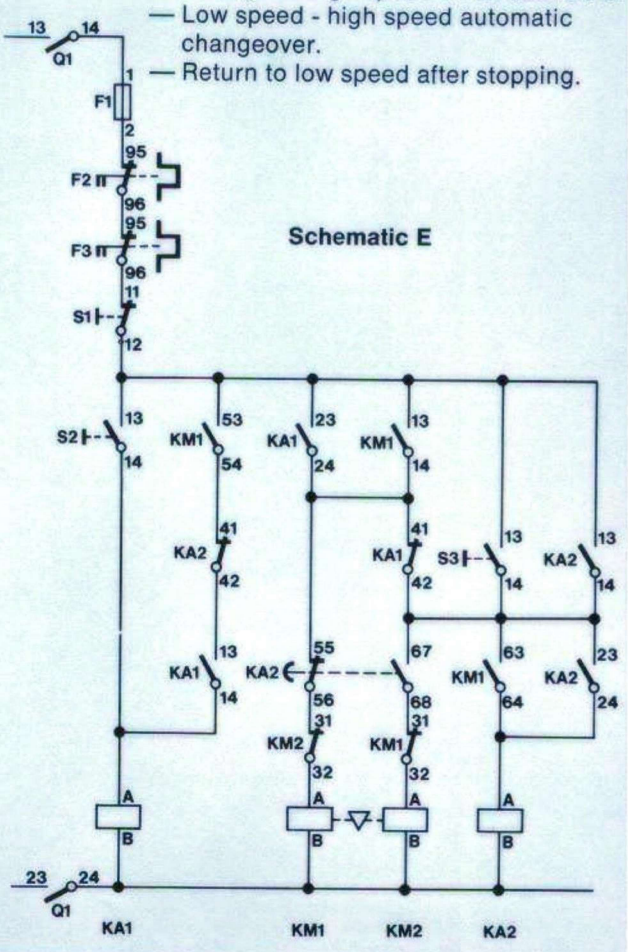
— Starting in low speed obligatory.
— Change to high speed when desired.
— Return to low speed after stopping.

Schematic D



— Starting in low speed obligatory.
— Change to high speed when desired or
— Low speed - high speed automatic changeover.
— Return to low speed after stopping.

Schematic E



REFERENCES OF AVAILABLE EQUIPMENT

• Enclosed equipment

Without isolator - With two thermal overload relays:
LE9-D12 or **D25** - Dust and damp protecting enclosure.

• Required equipment (schematics B-C)

Q1: 1 triple pole isolator (optional).
Rating: the highest Motor In: **LS1-D** or **DK1.**
3 main fuses. Rating: the highest Motor In.

KM1: 1 triple pole contactor + 1 N/C + 1 N/O auxiliary contacts. Rating: Motor In in low speed:
LC1; CN or **CV.**

KM2: 1 triple pole contactor + 1 N/C + 1 N/O auxiliary contacts. Rating: Motor In in high speed:
LC1; CN or **CV.**
Mechanical interlock between KM1 and KM2 recommended.

F2: 1 overload relay. Rating: Motor In in low speed:
— thermal: **LR1-D** or **RA1;**
— thermal magnetic: **RMT-D.**

F3: 1 overload relay. Rating: Motor In in high speed:
— thermal: **LR1-D** or **RA1;**
— thermal magnetic: **RMT-D.**

S1: 1 stop push button.

S2: 1 low speed start push button.
N/O contact (schematic B),
N/C + N/O contacts (schematic C).

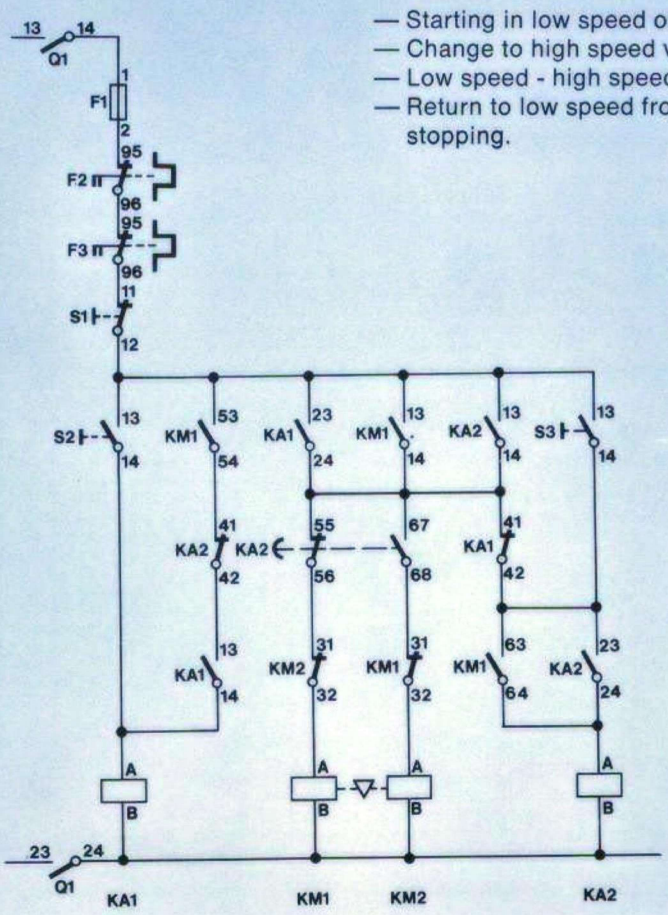
S3: 1 high speed start push button.
N/O contact (schematic B),
N/C + N/O contacts (schematic C).
XAB; XAF; XAG; XBF or **XB2.**

Equipment accessories.

Note: Since schematics D, E and F are rarely used we have not shown the list of required equipment.

* see page 105

— Starting in low speed obligatory.
— Change to high speed when desired or
— Low speed - high speed automatic changeover.
— Return to low speed from high speed after stopping.



Schematic F

Two speed starter - constant torque - tapped windings (Dahlander)

POWER CIRCUIT OPERATION

Manual closing of Q1.
Closing of KM1 - Motor energised at low speed

or

Closing of KM2 - Star connection of motor low speed terminals.
Closing of KM3 - Energization at high speed.

- **Feature**

Q1 - Rating: Motor In (highest value).
KM1 - Rating: Motor In at low speed.
KM2-KM3 - Rating: Motor In at high speed.
Electrical and mechanical interlock between KM1 and KM2.

To achieve mechanical interlocking it is sometimes necessary to use two contactors of identical size.

F2 - Rating: Motor In at low speed.
F3 - Rating: Motor at high speed.

CONTROL CIRCUIT OPERATION

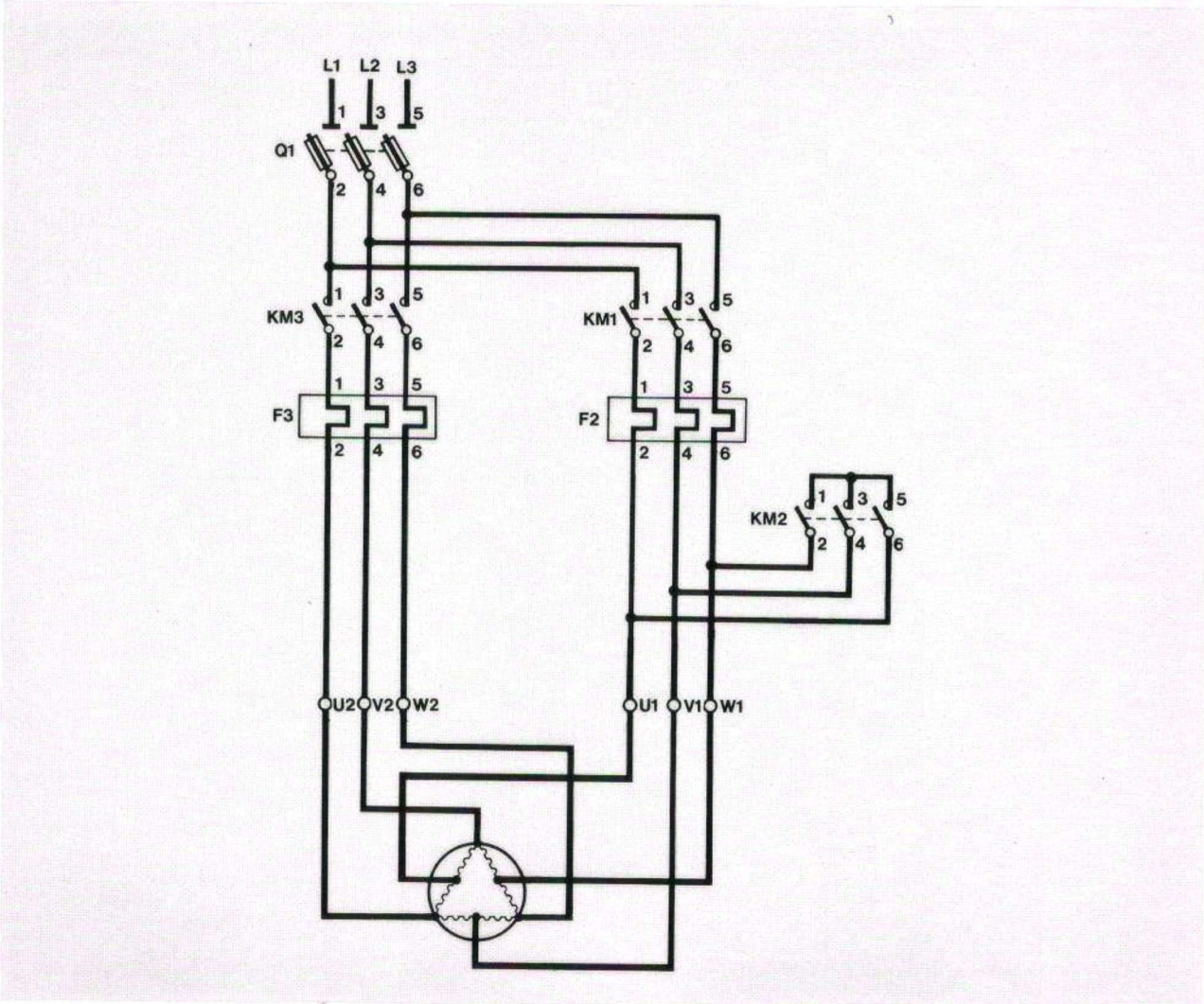
Operate S2.
Closing of KM1.
Interlock of KM2 and KM3 by KM1 (31-32).
Hold in of KM1 (13-14)

or

Operate S3.
Closing of KM2.
Interlock of KM1 by KM2 (31-32).
Closing of KM3 by KM2 (13-14).
Interlock of KM1 by KM3 (31-32).
Hold in of KM2 and KM3 by KM3 (13-14).
Stop: operate S1.

- **Features**

Mechanical and electrical interlock between KM1 and KM2.



REFERENCES OF AVAILABLE EQUIPMENT

• Enclosed equipment

Without isolator – with two thermal overload relays: **LE8-D12** or **D25** - Dust and damp protecting enclosure.

Q1: 1 triple pole isolator (optional).
Rating: the highest Motor In.
LS1-D or **DK1.**
3 main fuses. Rating: the highest Motor In (optional).

KM1: 1 triple pole contactor + 1 N/C + 1 N/O auxiliary contacts. Rating: Motor In in low speed:
LC1; CN or **CV.**

KM2: 1 triple pole contactor + 1 N/C + 1 N/O auxiliary contacts. Rating: Motor In in high speed:
LC1; CN or **CV.**
Mechanical interlock between KM1 and KM2 recommended.
In this case, use an unwired pair of contactors **LC2** or **NC2** or 2 contactors **LC1** or **CV,** mechanically interlocked.

KM3: 1 triple pole contactor + 1 N/C + 1 N/O auxiliary contacts. Rating: Motor In in high speed:
LC1; CN or **CV.**

F2: 1 overload relay. Rating: Motor In in low speed:
— thermal: **LR1-D** or **RA1;**
— thermal magnetic: **RMT-D.**

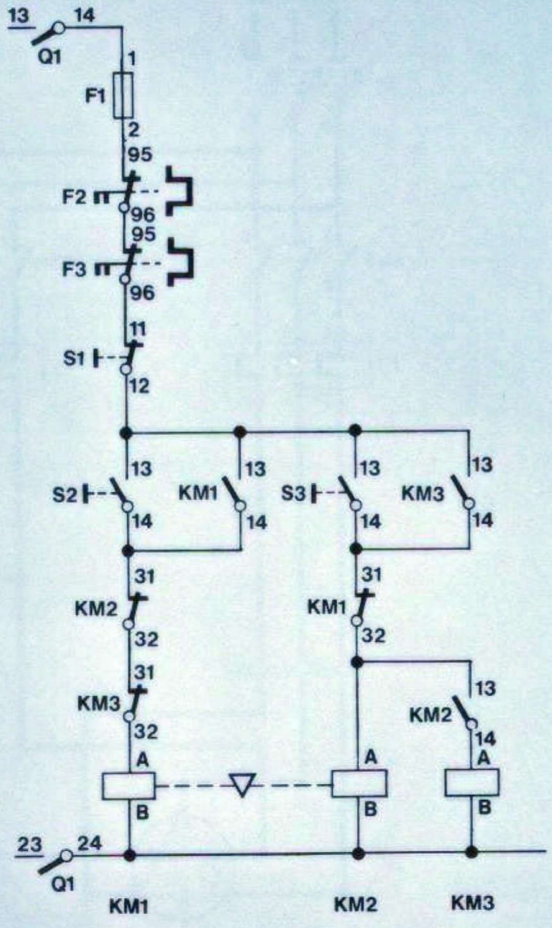
F3: 1 overload relay. Rating: Motor In in high speed:
— thermal: **LR1-D** or **RA1;**
— thermal magnetic: **RMT-D.**

S1: Stop push button.

S2: Low speed push button.

S3: High speed push button
XAB; XAF; XAG; XBF or **XB2.**
Equipment accessories.

* see page 105



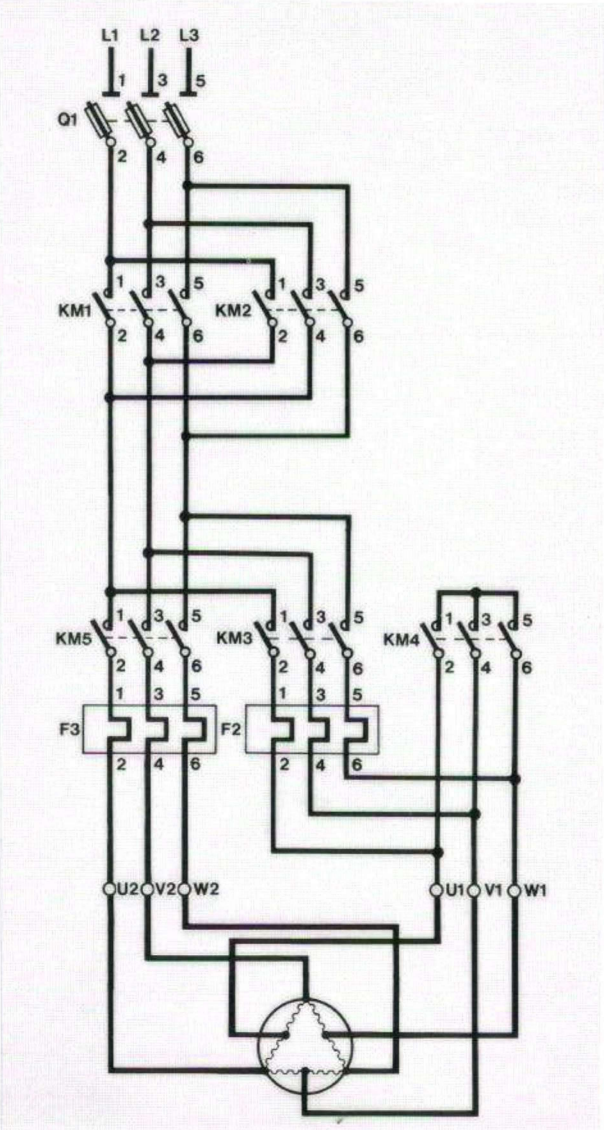
Two speed reversing starter - constant torque - tapped windings (Dahlander)

POWER CIRCUIT OPERATION

Manual closing of Q1.
Closing of KM1 or KM2 - Choice of direction of rotation.
Closing of KM3 - Motor starting in low speed or
Closing of KM4 - Star connection of motor low speed terminals.
Closing of KM5 - Energization of motor at high speed.

- **Features**

Q1 - Rating: highest value of Motor In.
KM1-KM2 - Rating: highest value of Motor In.
KM3 - Rating: Motor In at low speed.
KM4-KM5 - Rating: Motor In at high speed.



To mechanically interlock KM3 and KM4 it is sometimes necessary to use contactors of identical size.
F2 - Rating: Motor In at low speed.
F3 - Rating: Motor In at high speed.
Electrical and mechanical interlock between KM1 and KM2 and between KM3 and KM4.

CONTROL CIRCUIT OPERATION

Low speed forward:
Operate S2.
Closing of KM1.
Interlock of KM2 by KM1 (31-32).
Closing of KM3 by KM1 (53-54) and hold in of KM1 (13-14).
Interlock of KM4 and KM5 by KM3 (31-32).
Stop: by operating S1.

High speed forward:
Operate S4.
Closing of KM4.
Closing of KM5 by KM4 (13-14).
Interlock of KM3 by KM4 and KM5 (31-32).
Closing of KM1 by KM5 (13-14).
Interlock of KM2 by KM1 (31-32).
Hold in of KM1 (13-14).
Stop: by operating S1.

Low speed reverse:
Operate S3.
Closing of KM3.
Interlock of KM4 and KM5 by KM3 (31-32).
Closing of KM2 by KM3 (13-14).
Hold in of KM2 (13-14).
Interlock of KM1 by KM2 (31-32).
Stop: by operating S1.

High speed reverse:
Operate S5.
Closing of KM2.
Interlock of KM1 by KM2 (31-32).
Closing of KM4 by KM2 (53-54).
Interlock of KM3 by KM4 and KM5 (31-32).
Hold in of KM2 (13-14).
Stop: by operating S1.

- **Features**

Mechanical and electrical interlock between KM1 and KM2.
Mechanical and electrical interlock between KM3 and KM4.

- **Required equipment**

Q1: 1 triple pole isolator. Rating highest Motor In **LS1-D; DK1; LK1** (optional).
3 main fuses (optional). Rating: highest Motor In.

KM1+ KM2: 1 pair of triple pole contactors (mechanically interlocked) + 1 N/C + 2 N/O auxiliary contacts. Rating: highest Motor In. **LC2; NC2** or contactors **CV** or **LC1** mechanically interlocked.

KM3: 1 triple pole contactor + 1 N/C + 1 N/O auxiliary contacts. Rating: Motor In in low speed: **LC1; CN** or **CV.**

KM4: 1 triple pole contactor + N/C + N/O auxiliary contacts. Rating: Motor In in high speed: **LC1; CN** or **CV.**

Mechanical interlock between KM3 and KM4 recommended.
In this case, use an unwired pair of contactors **LC2, NC2** or two contactors **CV** or **LC1** mechanically interlocked.

KM5: 1 triple pole contactor + 1 N/C + 1 N/O auxiliary contacts. Rating: Motor In in high speed: **LC1; CN** or **CV.**

F2: 1 overload relay. Rating: Motor In in low speed:
— thermal: **LR1-D** or **RA1;**
— thermal magnetic: **RMT-D.**

F3: 1 overload relay. Rating: Motor In in high speed:
— thermal: **LR1-D** or **RA1;**
— thermal magnetic: **RMT-D.**

S1: Stop push button.

S2: Low speed forward push button.

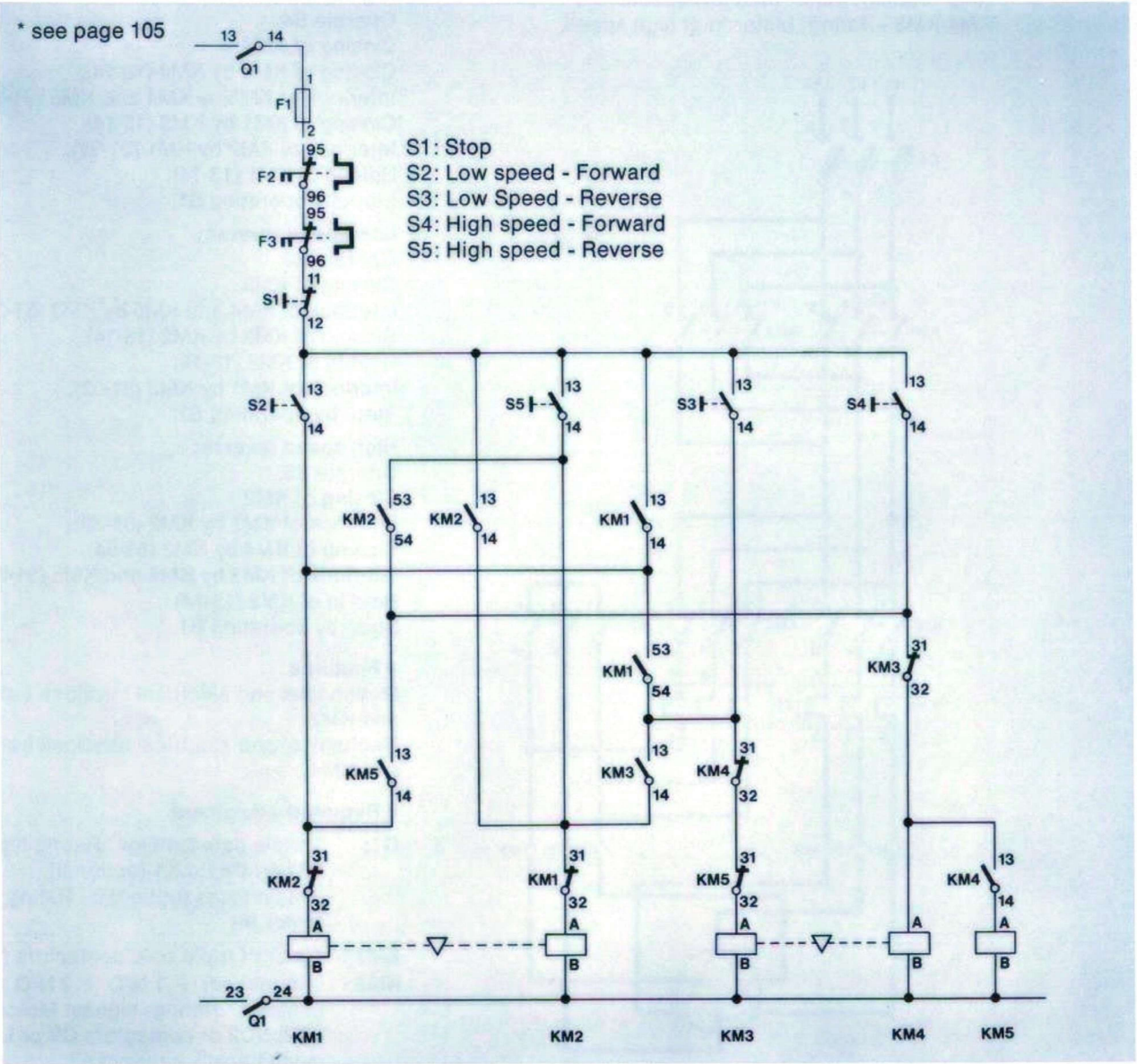
S3: Low speed reverse push button.

S4: High speed forward push button.

S5: High speed reverse push button
XAB; XAF; XAG; XBF or **XB2.**

Equipment accessories.

* see page 105



3 Step rotor starter

POWER CIPCUIT OPERATION

Manual closing of Q1.
Closing of KM1 - Motor energised.
Closing of KM11 - Shorting out a part of the resistance.
Closing of KM12 - Shorting out all of the resistance.

- **Features**

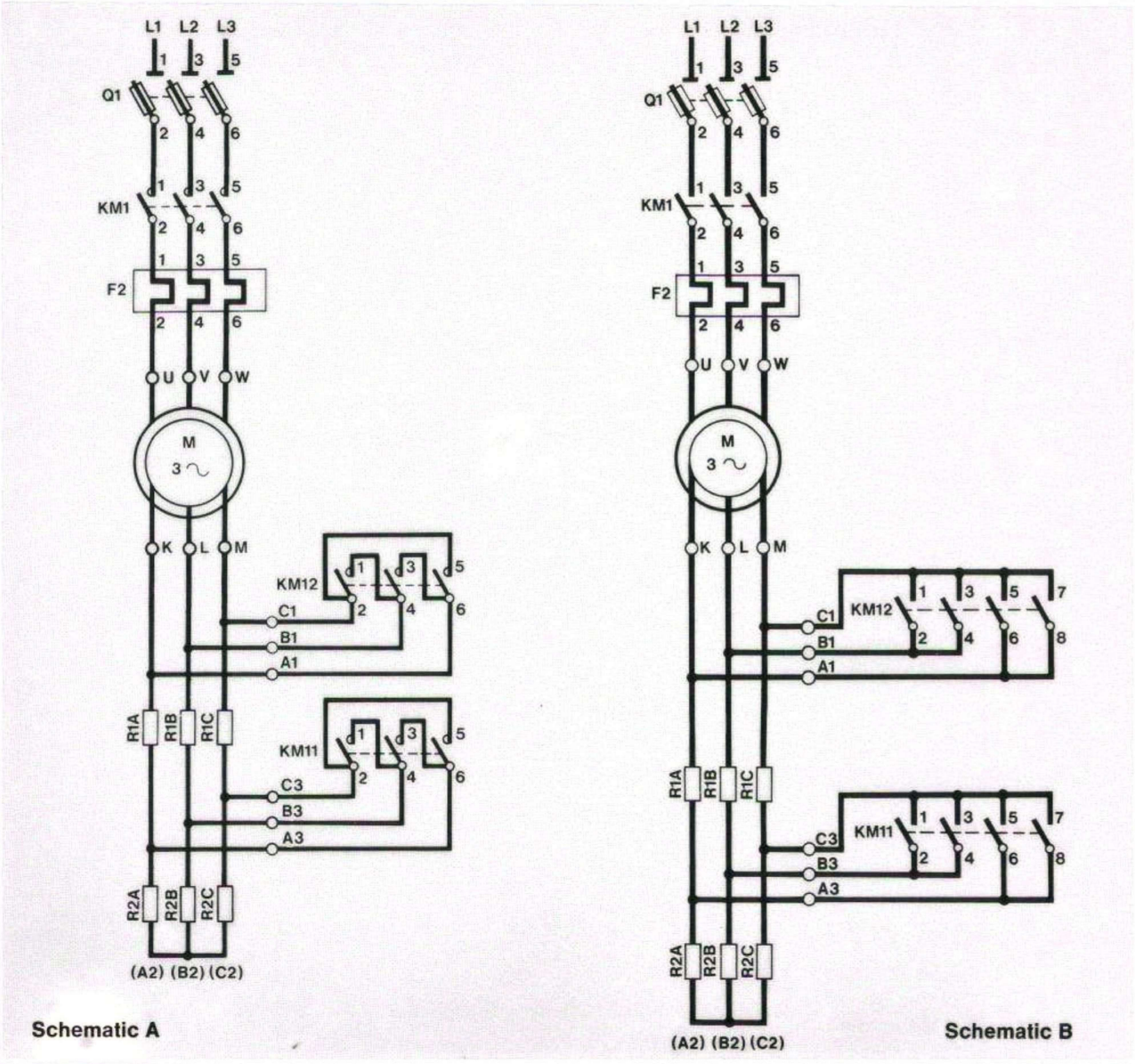
Q1 - Rating: Motor In.
KM1 - Rating: Motor In.
KM11 - Number of poles and rating depend upon the rotor current and duty cycle.
KM12 - Rating: rotor current.
F2 - Rating Motor In.

CONTROL CIRCUIT OPERATION (schematic C)

Operate S2.
Closing of KM1.
Hold in of KM1 (13-14).
Energization of thermal relay F3 by KM1 (53-54).
Closing of KM11 by KM1 (67-68).
Closing of KM12 by KM11 (67-68).
De-energization of F3 by KM12 (31-32).
Stop: by operating S1.

- **Features**

F3 - Thermal relay for protection of resistors against incomplete or too frequent starting.



starting of slipring motors

CONTROL CIRCUIT OPERATION (schematic D)

Operate S2.
Closing of KM1.
Hold in of KM1 (13-14).
Closing of KA1 by KM1 (53-54) and energization of thermal relay F3.
Closing of KM11 and KA2 by KA1 (67-68).
Closing of KM12 by KA2 (67-68).
De-energization of F3 by KM12 (31-32).
Stop: by operating S1.

- **Features**

F3 - Thermal relay for protection of resistors against incomplete or too frequent starting.

REFERENCES OF AVAILABLE EQUIPMENT

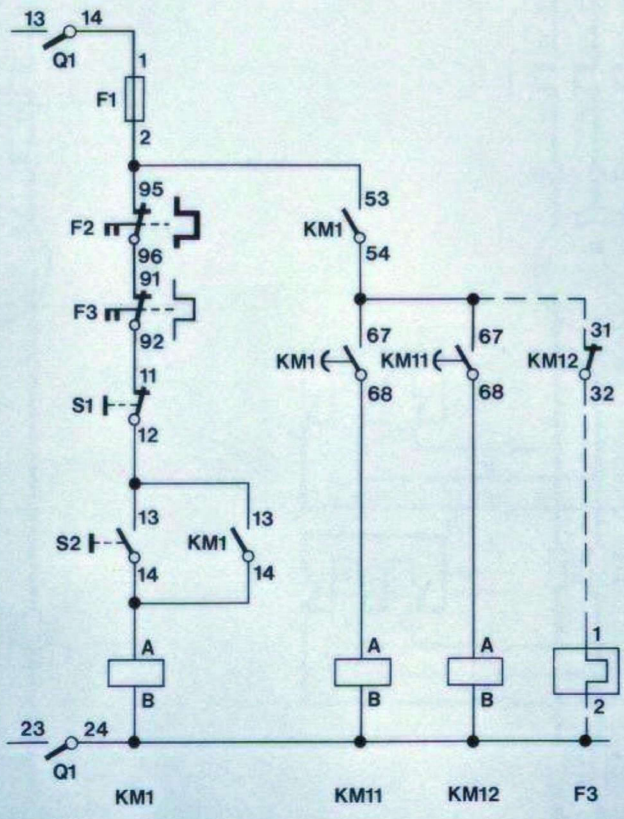
- **Open type starters**

With or without isolator - with thermal overload relay - with starting resistors.
LC6-D or **NR1.**

- **Enclosed starters**

With or without isolator - with thermal overload relay - with starting resistance.
LE6-D; NR1.

* see page 105



Schematic C

REQUIRED EQUIPMENT

Q1: 1 triple pole isolator. Rating: Motor In: **DK1.**
3 main fuses (optional). Rating: Motor In.

KM1: 1 triple pole contactor + 2 N/O auxiliary contacts + adder block with time delay on energization.
Rating: Motor In: **LC1; CN** or **CV.**
If **LC1-F** or **CN,** use a separate timing relay with time delay on energization (KA1 on schematic D).

KM11: 1 triple or 4 pole contactor + adder block with time delay on energization - number of poles and rating depend upon the rotor current and duty cycle.
LC1; CN or **CV.**
If **LC1-F** or **CN,** use a separate timing relay with time delay on energization (KA2 on schematic D).

KM12: 1 triple or 4 pole contactor + 1 N/C auxiliary contact - number of poles and rating depend upon the rotor current:
LC1; CN or **CV.**

KA1+ KA2: 2 timing relays with time delay on energization (only if KM1 and KM11 are **LC1-F** or **CN).**
CA2-AN + CA2-AS22; CA2-DN + LA2-D22; CA2-FT.
Usual time delays: 5 to 7 sec.

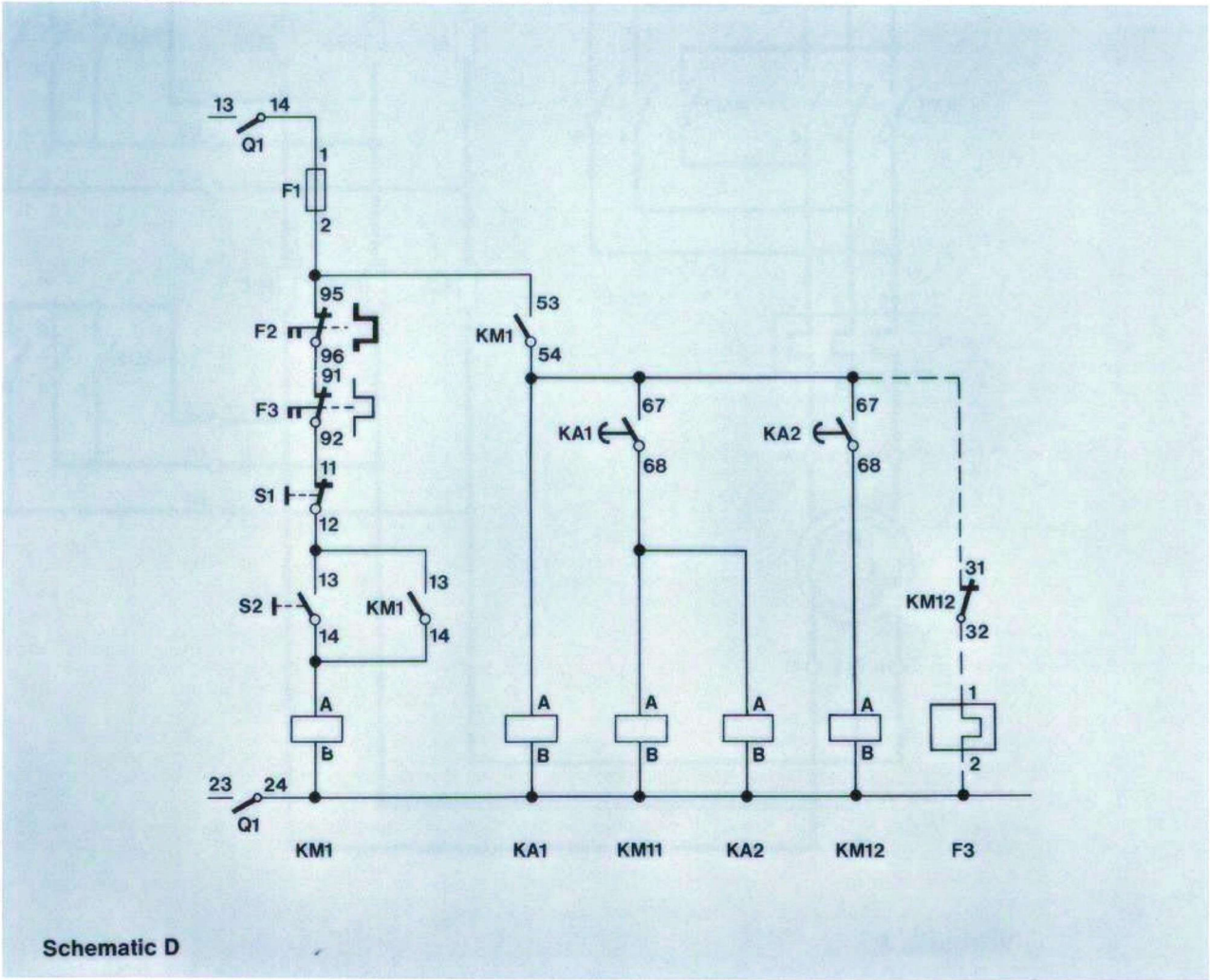
F2: 1 overload relay. Rating: Motor In:
— thermal: **LR1-D** or **RA1;**
— thermal magnetic: **RMT-D.**

F3: 1 thermal relay (optional). Protection of starting resistance.
RT1-TK.
Usual time delay equals 2 to 3 consecutive starts.

RA+ RB+ RC Starting resistance - value depends upon the motor power and rotor characteristics.

S1: Stop push button.

S2: Start push button
XAB; XAF; XAG; XBF or **XB2.**
Equipment accessories.



Schematic D

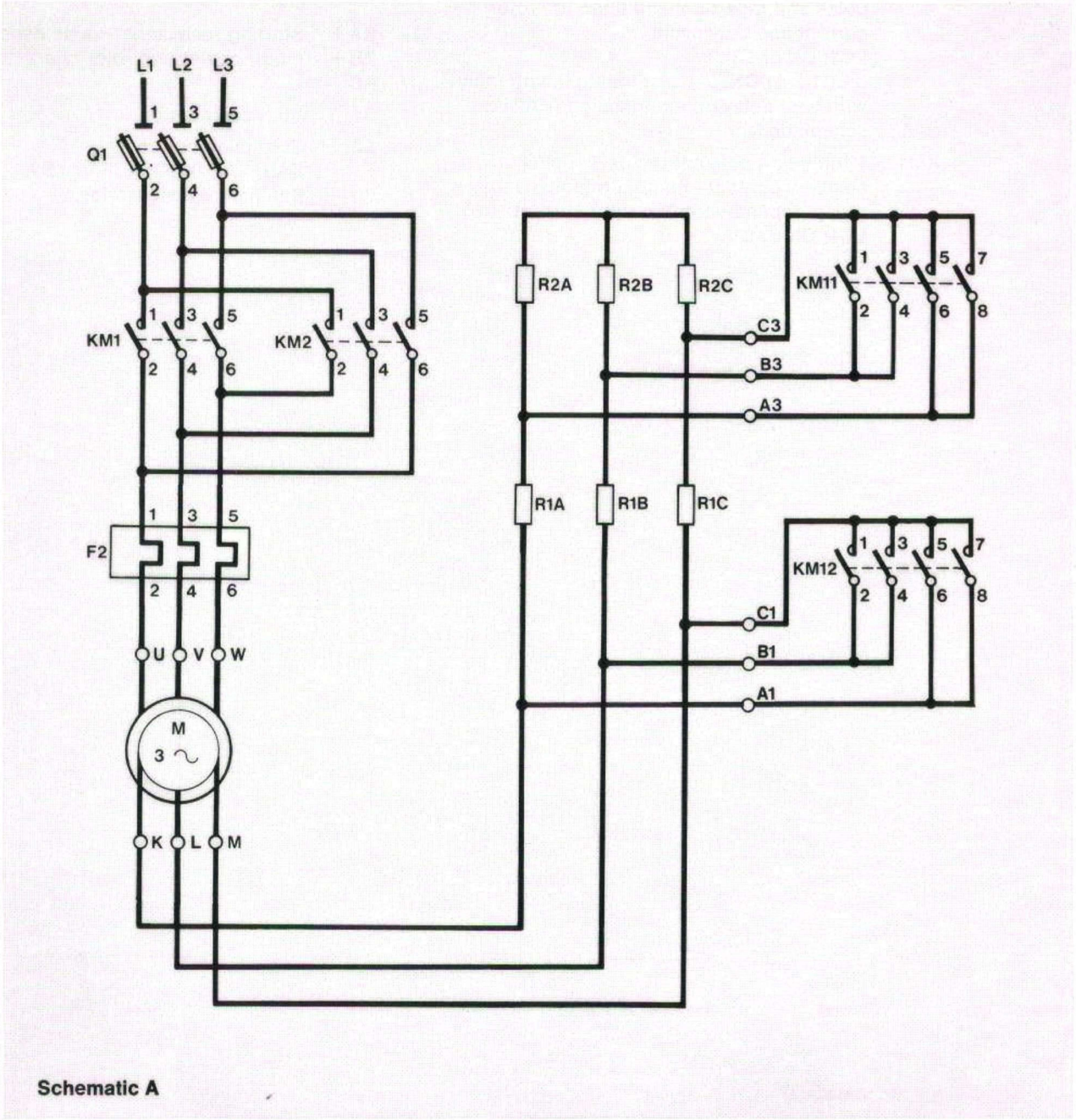
3 Step rotor reversing starter
(push button control)

POWER CIRCUIT OPERATION
(schematics A and B)

Manual closing of Q1.
Closing of KM1 or KM2 - Choice of direction of rotation - Motor energised.
Closing of KM11 - Shorting out of part of the resistance.
Closing of KM12 - Shorting out of all the resistance.

- **Features**

Q1 - Rating: Motor In.
KM1-KM2 - Rating: Motor In.
KM11 - Number of poles and rating depend upon the rotor current and duty cycle.
KM12 - Rating: rotor current.
F2 - Rating: Motor In.



Schematic A

POWER CIRCUIT OPERATION
(schematic C)

Operate S2 ou S3.
Closing of KM1 or KM2.
Interlock of KM2 or KM1 (31-32).
Hold in of KM1 or KM2 (13-14).
Closing of KA1 by KM1 or KM2 (53-54) and energization of thermal relay F3.
Closing of KM11 by KA1 (67-68).
Closing of KM12 by KM11 (67-68).
De-energization of F3 by KM12 (31-32).
Stop: by operating S1.

- **Features**

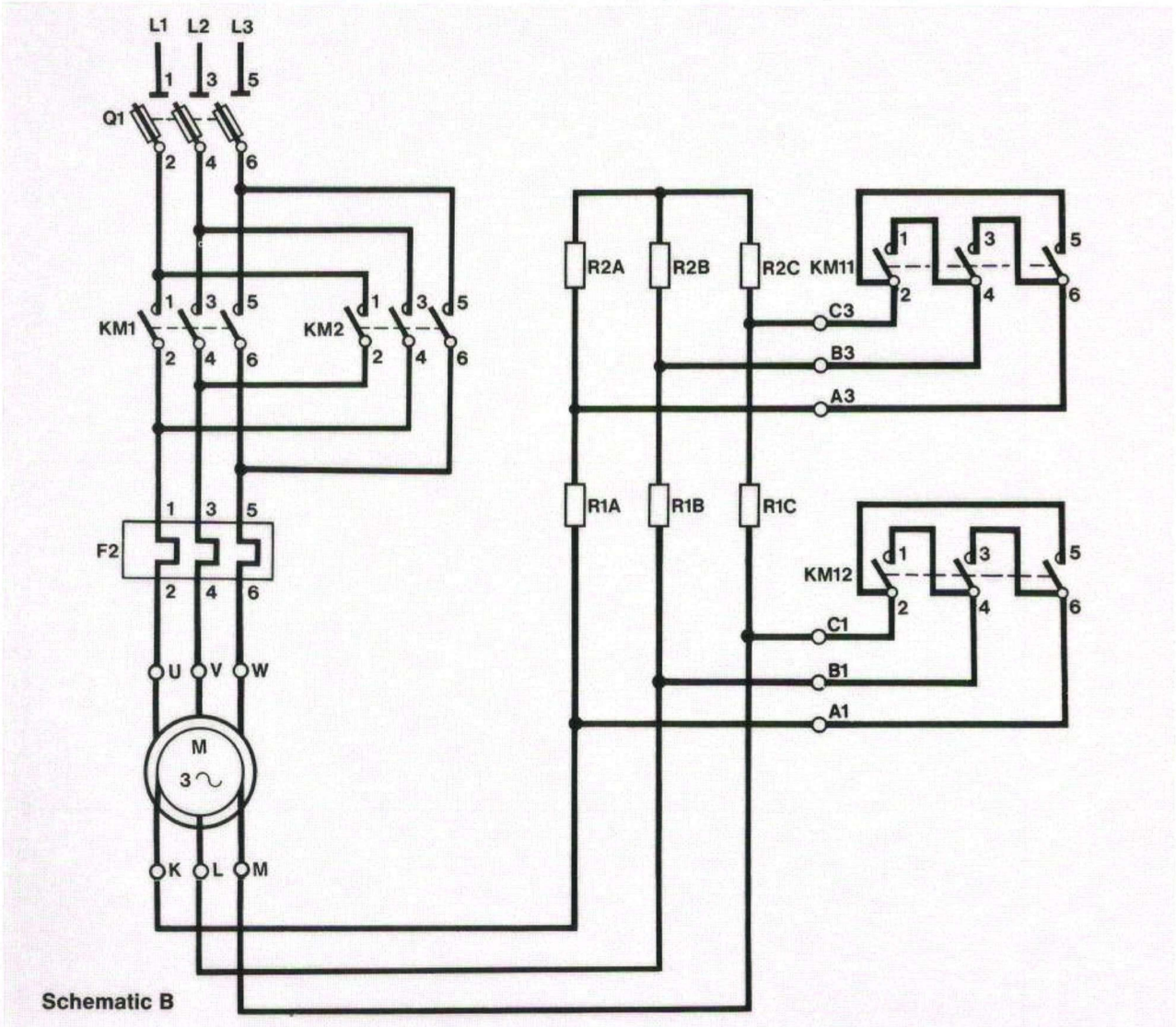
Mechanical and electrical interlock between KM1 and KM2.
F3 - Thermal relay protecting starting resistors against incomplete of too frequent starting.

CONTROL CIRCUIT OPERATION
(schematic D)

Operate S2 or S3.
Closing of KM1 or KM2.
Interlock of KM2 or KM1 (31-32).
Hold in of KM1 or KM2 (13-14).
Closing of KA1 by KM1 or KM2 (53-54) and energization of thermal relay F3.
Closing of KM11 and KA2 by KA1 (67-68).
Closing of KM12 by KA2 (67-68).
De-energization of F3 by KM12 (31-32).
Stop: by operating S1.

- **Features**

Mechanical and electrical interlock between KM1 and KM2.



Schematic B

REQUIRED EQUIPMENT

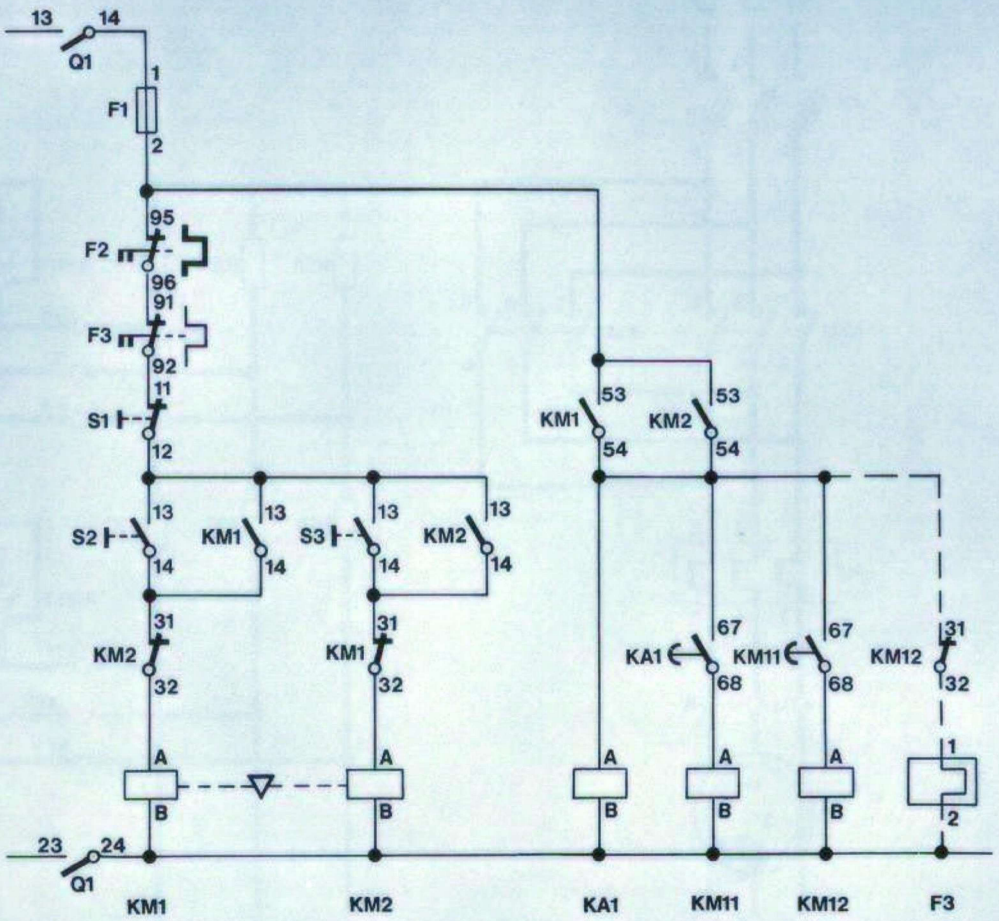
Q1: 1 triple pole isolator. Rating: Motor In: **DK1.**
3 main fuses (optional). Rating: Motor In.

KM1+ KM2: 1 unwired pair of triple pole contactors each having 1 N/C + 2 N/O auxiliary contacts. Rating: Motor In: **LC2; NC2** or 2 contactors **CV** or **LC1,** mechanically interlocked.

KM11: 1 triple or 4 pole contactor plus adder block with time delay on energization.
Number of poles and rating depend upon the rotor current and duty cycle.
LC1; CN or **CV.**
If **LC1-F** or **CN,** use a timing relay with time delay on energization (KA2 on schematic D).

KM12: 1 triple or 4 pole contactor + 1 N/C auxiliary contact.
Number of poles and rating depend upon the rotor current.
LC1; CN or **CV.**

* see page 105



KA1: 1 timing relay with time delay on energization: **CA2-AN + CA2-AS22; CA2-DN + LA2-D22; CA2-FT.**
Usual time delay: 3 to 7 sec.

KA2: (only if KM11 is **LC1-F** or **CN**) **CA2-AN +CA2-AS22; CA2-DN + LA2-D22** or **CA2-FT.**

F2: 1 overload relay. Rating: Motor In:
— thermal: **LR1-D** or **RA1,**
— thermal magnetic: **RMT-D.**

F3: 1 thermal relay for protection of starting resistance (optional): **RT1-TK.**
Usual time delay equals 2 to 3 consecutive starts.

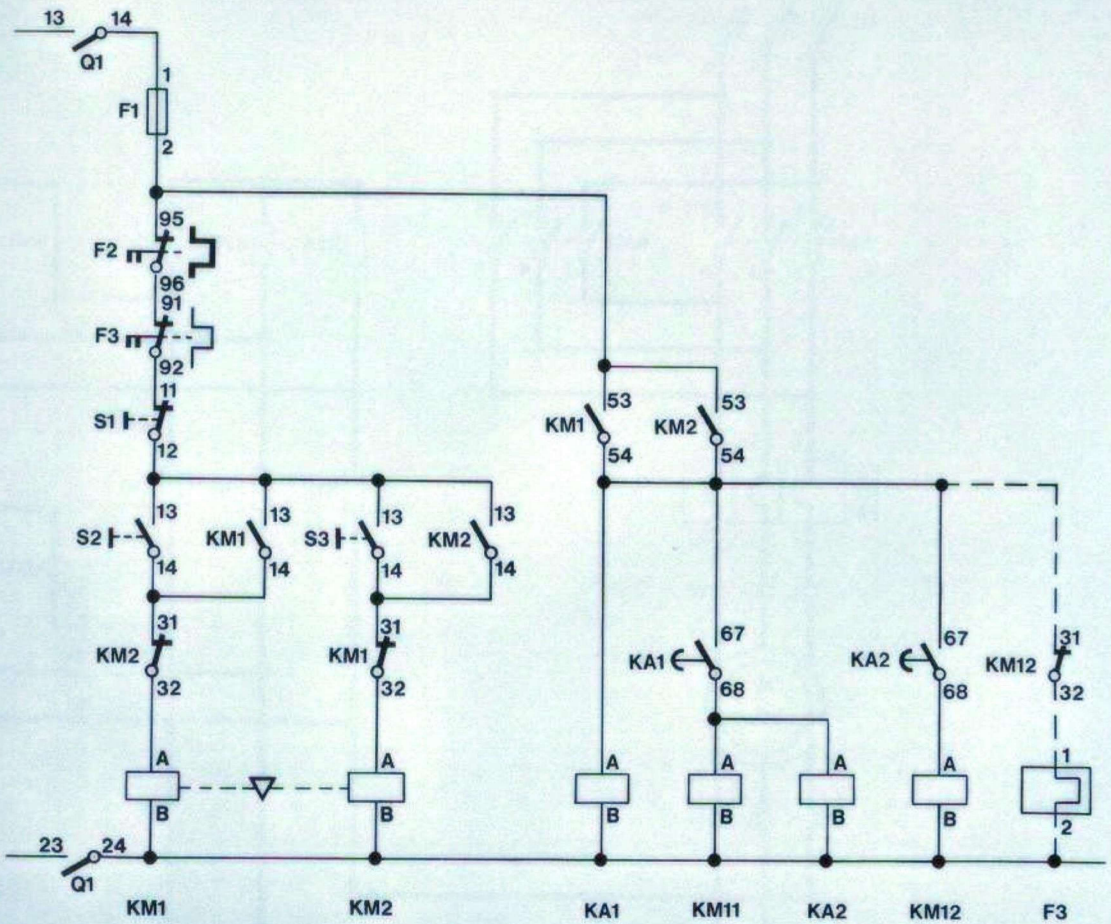
RA+ RB+ RC: Starting resistance - Value depends upon the motor power and rotor characteristics.

S1: Stop push button.

S2: Forward push button.

S3: Reverse push button
XAB; XAF; XAG; XBF or **XB2.**
Equipment accessories.

* see page 105



Schematic D

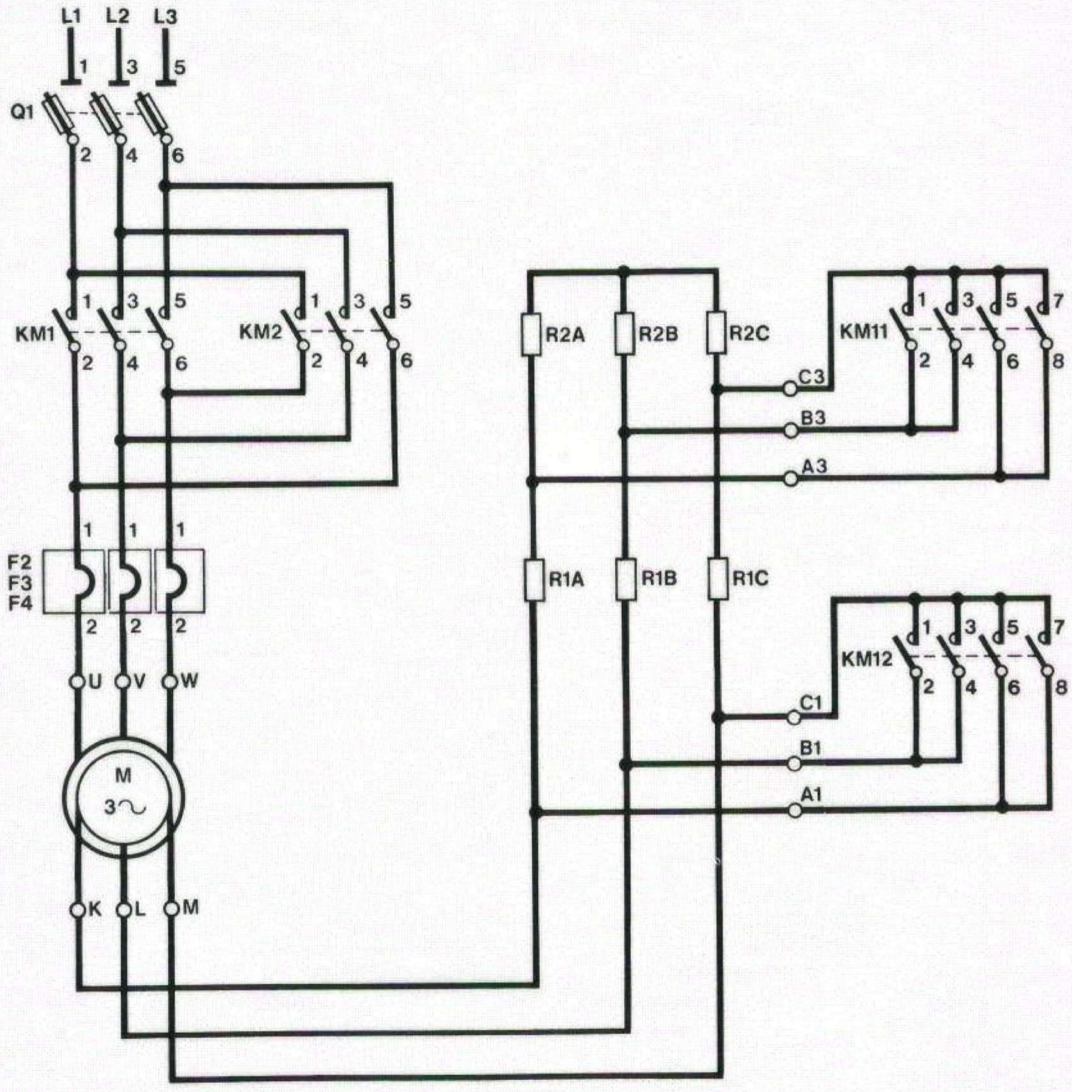
3-Step rotor reversing starter
(operated by a controller)

POWER CIRCUIT OPERATION
(schematics A and B)

Manual closing of Q1.
Closing of KM1 or KM2 - Choice of direction of rotation - Motor energised.
Closing of KM11 - Shorting out of part of the resistance.
Closing of KM12 - Shorting out of all the resistance.

- **Features**

Q1 - Rating: Motor In.
KM1-KM2 - Rating: Motor In.
KM11-KM12 - Rating: rotor current.
F2-F3-F4 - Rating: Motor In.

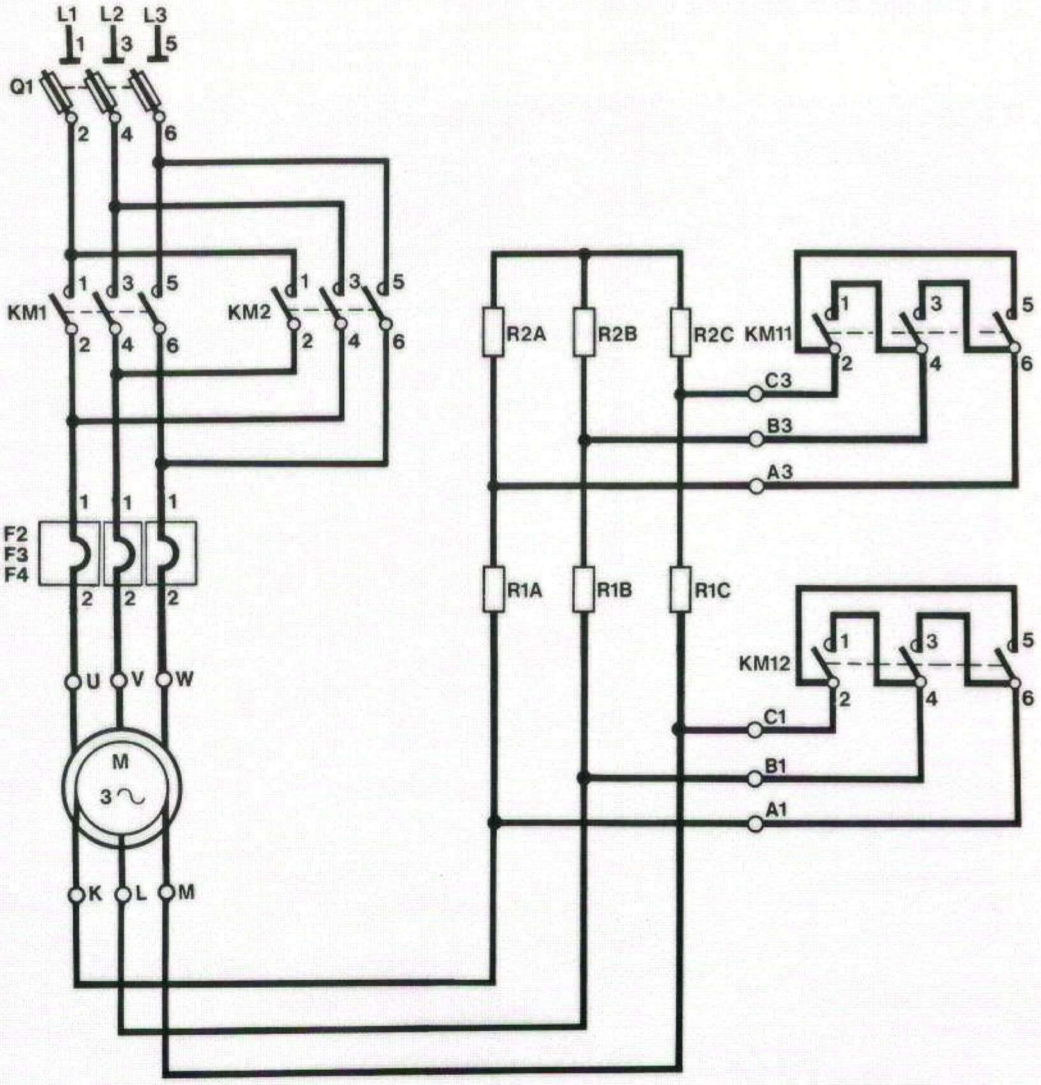


Schematic A

CONTROL CIRCUIT OPERATION (schematic C)

• Controller S3 on zero (contact S31 closed):
Operate S2.
Closing of KA1.
Hold in of KA1 (13-14).
Closing of KA1 (23-24).
• Controller S3 on 1 FWD or 1 REV:
Opening of contact S31.
Closing of contact S32 or S33.
Closing of KM1 or KM2.
Interlock of KM2 or KM1 (31-32).
Closing of KA2 by KM1 or KM2 (13-14).
• Controller S3 on 2 FWD or 2 REV:
Closing of contact S34.
Closing of KM11 by KA2 (67-68).
• Controller S3 on 3 FWD or 3 REV:
Closing of contact S35.
Closing of KM12 by KM11 (67-68).
• Stopping:
By returning controller S3 to zero position.
KA1 remains closed.
By operating S1: opening of KA1.
To re start, the controller must be placed in the zero position and S2 must be pressed.

• **Feature**
Mechanical and electrical interlock between KM1 and KM2.



Schematic B

CONTROL CIRCUIT OPERATION
(schematic D)

- Controller S3 on zero (contact S31 closed):

Operate S2.
Closing of KA1.
Hold in of KA1 (13-14).
Closing of KA1 (23-24).

- Controller S3 on 1 FWD or 1 REV:

Opening of contact S31.
Closing of contact S32 or S33.
Closing of KM1 or KM2.
Interlock of KM2 or KM1 (31-32).
Closing of KA2 by KM1 or KM2 (13-14).

- Controller S3 on 2 FWD or 2 REV:

Closing of contact S34.
Closing of KM11 and KA3 by KA2 (67-68).

- Controller S3 on 3 FWD or 3 REV:

Closing of contact S35.
Closing of KM12 by KA3 (67-68).

- Stopping as in schematic C.

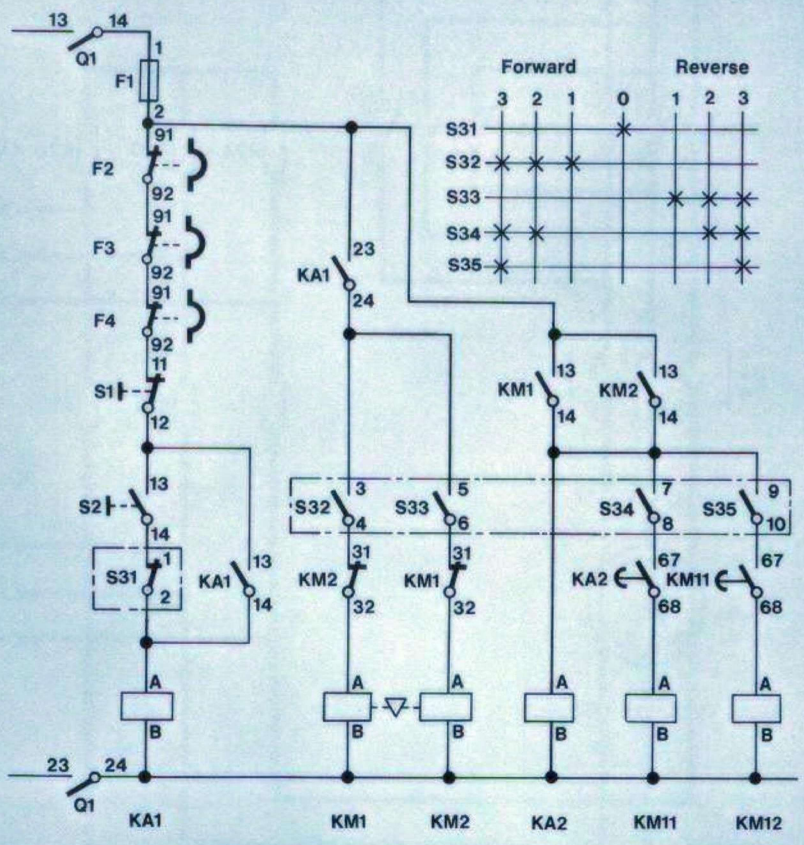
REQUIRED EQUIPMENT

Q1: 1 triple pole isolator. Rating: Motor In: **DK1.**
3 main fuses (optional). Rating: Motor In.

KM1 + KM2: 1 unwired pair of triple pole contactors each having 1 N/C + 1 N/O auxiliary contacts. Rating: Motor In.
LC2; NC2; or 2 contactors **CV or LC1** mechanically interlocked.

KM11: 1 triple or 4 pole contactor + adder block **LC2; NC2;** or 2 contactors, **CV** or **LC1,** mechanically interlocked.
with time delay on energization. Number of poles and rating depend upon the rotor current: **LC1; CN** or **CV.**
If **LC1** or **CN** use a timing relay with time delay on energization (KA3 on schematic D).

* see page 105



Schematic C

KM12: 1 triple or 4 pole contactor. Number of poles and rating depend upon the rotor current: **LC1; CN** or **CV.**

KA1: 1 control relay, N/O + N/O **CA2-AN; CA2-DN** or **CA2-F.**

KA2: 1 timing relay with time delay on energization: **CA2-AN +CA2-AS22; CA2-DN + LA2-D2** or **CA2-FT.**

KA3: 1 timing relay with time delay on energization (only if KM11 is **LC1-F** or **CN**): **CA2-AN + CA2-AS22; CA2-DN + LA2-D22** or **CA2-FT.**

F2+ **F3+** 3 electromagnetic relays (1 per phase): **RM1-XA** with or without latching depending upon application.

F4: Rating: Motor In.

RA+ **RB+** **RC:** 1 starting resistance - Valve depends upon the power and rotor characteristics of the motor.

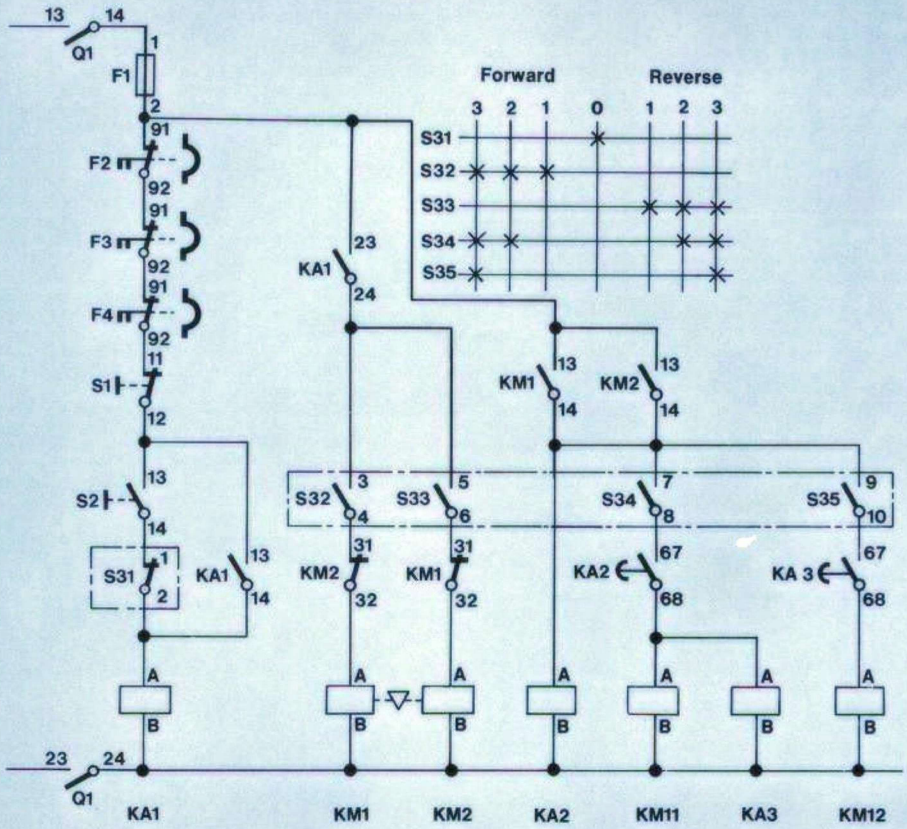
S1: Stop push button.

S2: Start push button **XAB; XAF; XAG; XBF; XB2.**

S3: 1 heavy duty controller **XKM; XK2-B; XK3-B** or **XK4-C.**

Equipment accessories.

* see page 105



Schematic D

design of control panels

All of the control equipment manufactured by Telemecanique is suited for use with our mounting and wiring system. It should be mentioned that these accessories allow:

• panels to be produced, without machining and ready to be wired, with a useful area of from 2.1 dm^2 up to a maximum of several square metres:
— reduction of assembly time.
• the production, without previous layout work, of panels with a useful area of from 2.1 to 68.7 dm^2 by direct mounting of apparatus on our universal pre-slotted plates:
— average area gain of 25%.
• mounting of all parts from the front:
— easier modifications or additions.
• all equipment wiring from the front:
— fast wiring, easy modifications and additions.
• practical and neat terminal connections using our multi-way terminal blocks with screw-in test points and clip-in referencing.
— time saving of 60% on average.
— simple and low cost connections.
— savings in cost of 50%.
— saving in wiring time.
• In particular, all components:
— are mounted from the front on pre-slotted plates by means of clip nuts and on mounting rails by means of sliding clamps inserted from the front.
— are easily wired from the front with "TELEQUICK" cable clips.
• are connected simply with insulated cable ends.
This range includes drawing office aids to determine space requirements, and layout of apparatus plus suitable enclosures.

panel layout and calculation of overall dimensions

DETERMINATION OF OVERALL DIMENSIONS

Three methods can be used to determine, in a minimum of time, the space requirements of a panel.

DIRECT MOUNTING METHOD FOR SMALLER PANELS

This method is applicable to a panel whose dimensions are not more than 960 x 734 mm. Components are positioned directly on a full size layout sheet having the outline of the pre-slotted plate. The space requirements of the panel are thus determined quickly and economically without any special planning beforehand.

LAYOUT METHOD USING ADHESIVE TEMPLATES

This method is based on a complete range of transparent adhesive templates representing, on a scale of 1:5, all components manufactured by Telemecanique. Dimensions are determined by positioning the templates on a layout sheet which is also transparent. The completed layout can then be copied to obtain the drawings required for production and engineering files. The templates and layout sheet are recoverable for later use.

AREA CALCULATION METHOD

This is a very accurate and rapid method to determine the space requirements of a panel. The method is as follows:

Equipment mounted on "TELEQUICK" plates

1. Add up the areas required by each component in the panel (Table A).
2. Multiply the total by the following factor which takes into account wiring and terminals:
2 for a maximum total area up to 34.3 dm^2
2.3 for a total area of more than 34.3 dm^2.
3. The result is the total useful area of the panel. Referring to the "useful area" column of the plate tables, select the mounting plate (for mounting inside an enclosure Table B) or plates (for mounting on predrilled uprights Table C).

Equipment on "DIN" mounting rails

1. Using Table A, add up the areas required by each component in the panel.
2. Multiply the total by a factor of:
2.2 for equipment on small frames.
2.5 for equipment on large frames.
The result is the total area of the equipment in dm^2.
3. Select from the tables:
D: small frames.
E: large frames.
the optimum plate and its fixing centres.

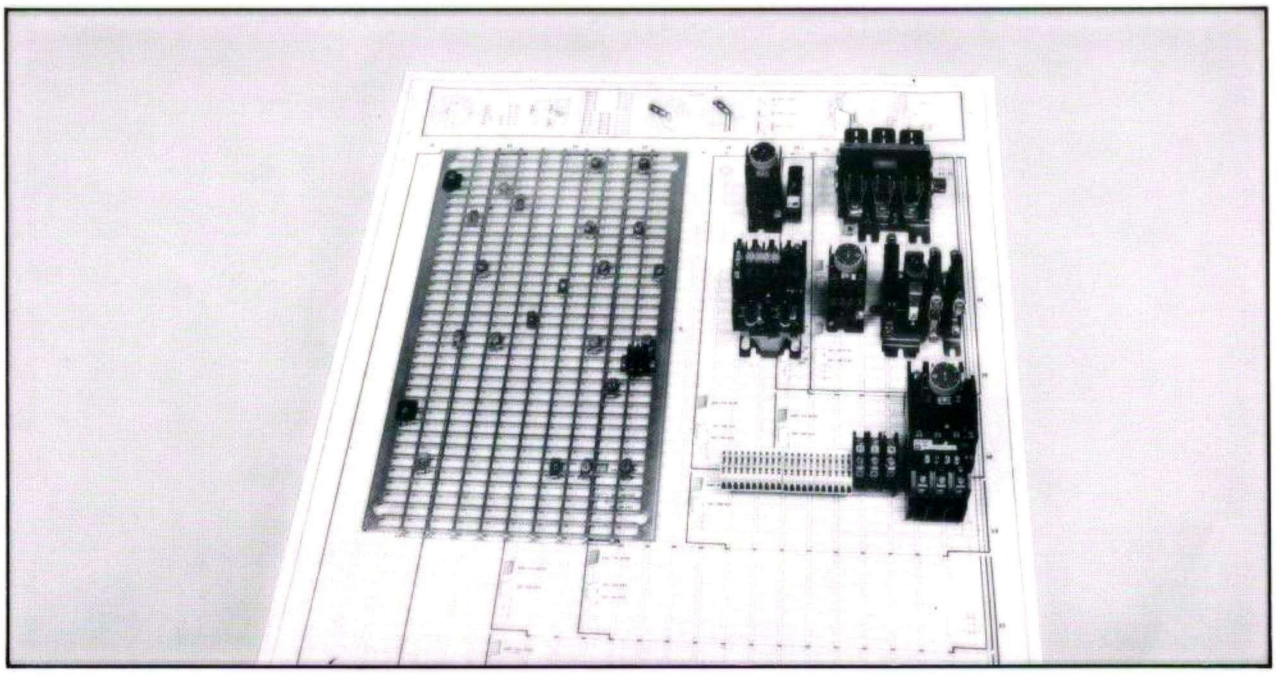


TABLE « A »
Table of overall areas (in dm^2) of the principal Telemecanique products

Relays

CA2-AS 202 and 204	0.7
CA2-AD4	0.3
CA2-AK4	0.7
CA2-AN2	0.4
CA2-AN4	0.5
CA2-AP3	0.4
CA2-AP6	0.8
CA2-AS22 and 24	0.3
CA2-DK	0.6
CA2-DN	0.3
CA2-FK	0.4
CA2-FN1 and 2 (4 contacts)	0.2
CA2-FN1 and 2 (8 contacts)	0.3
CA2-FT and FR	0.4

Contactors 9 to 1,000 A

LC1-D09 and 12 A	0.3
LC1-D16 and 25 A	0.5
LC1-D40 and 63 A three-pole	1
LC1-D40 and 63 A four-pole	1.1
CN1-FC	1.7
CN1-GC	2.2
CN1-HC	3.2
CN1-JC	3.5
LC 1 - FJ 22 and 23	4.6
LC 1 - FJ 24	5.6
LC 1 - FK 22 and 23	5.7
LC 1 - FK 24	6.7
LC 1 - FL 22 and 23	9.5
LC 1 - FL 24	12.1

Overload relays

LR1-D09, 12, 16 and 25 A	0.3
LR1-D09 (with independent mounting)	0.61
LR1-D40 and 63 A	0.5
RA1-FA and GA	1.7
RA1-HA	2
RM1-XA 1.6 to 40 A	0.7
RM1-XA 63 to 200 A	1
RM1-XA 315 A	1.1
RMT-D 321 and 322	3.3
RT1-TK	1.1
LR 1* - FS 250 and 315	3.1
LR 1* - FK 400	3.1
LR 1* - FK 500	3.4
LR 1* - FL 630	3.4
LR 1* - FL 800 and 1000	4.1

* Same dimension for LR3 and LR5

Isolators

LS1-D253	0.42
LS1-D253 + LA8-D254	0.6
LS1-D253 + 2 LA8-D254	0.78
DK1-EB	1.5
DK1-FB	2.5
DK1-GB	3.3
DK1-HC	8.8
DK1-JC	11.9
DK1-KC	13.4
DK2-LC	18.9

PREASSEMBLED UNITS

Contactor + Isolator

LC4-D09 and 12 A	1.9
LC4-D16 and 25 A	3.5
LC4-D40 and 63 A	4

Reversing contactor

LC2-D09 and 12 A horizont. interl.	0.7
LC2-D16 and 25 A horizont. interl.	1
LC2-D40 and 63 A horizont. interl.	2.1
NC2-FC horizontally interlocked	5
NC2-FC vertically interlocked	6.2
ND2-GC horizontally interlocked	6
NC2-GC vertically interlocked	6.8
NC2-HC horizontally interlocked	8.5
NC2-HC vertically interlocked	9.4
NC2-JC horizontally interlocked	7.3

Contactor + overload relay

LC1-D09 and 12 A + LR1	0.5
LC1-D16 and 25 A + LR1	0.7
LC1-D40 and 63 A three-pole + LR1	1.4
LC1-D40 and 63 A four-pole + LR1	1.5

Isolator + Contactor + Overload relay

LC4-D09 and 12 A	2.3
LC4-D16 and 25 A	3.5
LC4-D40 and 63 A	5.1

Reversing contactor + overload relay

LC4-D09 and 12 A horizont. interl.	1.1
LC4-D16 and 25 A horizont. interl.	1.5
LC4-D40 and 63 A horizont. interl.	2.9

TABLE "B"
Mounting plates in enclosures - area < 68.7 dm²

h	l	Useful area dm²	Corresponding enclosure*	Référence**
237	102	3	AC1-EA 28 16 15 EB 31 18 14	AM1-PC 2615
333	108	5,6	AC1-EA 40 18 15 EB 44 20 15	AM1-PC 3516
219	190	4,2	AC1-EB 30 26 16	AM1-PF 2422
279	220	6,2	AC1-EB 37 29 19	AM1-PF 3025
200	150	3,7	DE1-GB 2151	AM1-PA 2015
300	150	5,3	DE1-GB or SB 3151	AM1-PA 3015
300	200	7,4	DE1-GB or SB 322	AM1-PA 3020
400	200	9,6	DE1-GB 422	AM1-PA 4020
400	300	13,8	DE1-GB or SB 433	AM1-PA 4030
500	300	16,4	DE1-GB 533	AM1-PA 5030
500	400	23,1	DE1-GB or SB 543	AM1-PA 5040
600	400	27,4	DE1-GB or SB 643	AM1-PA 6040
600	500	33,4	DE1-GB 654	AM1-PA 6050
700	500	38,7	DE1-GB or SB 754	AM1-PA 7050
800	600	51	DE1-GB or SB 864	AM1-PA 8060
900	700	68,7	DE1-GB or SB 974	AM1-PA 9070

* Enclosures AC1-EA-EB and DE1-GC or SC are supplied with their mounting plate.
** Mounting plates for enclosures DE1-GB or SB are supplied with 4 washers.
h-l: mounting plate fixing centres.

TABLE "D"
Small panels (for mounting in enclosures)
Fixing centres

Vertical in mm	Horizontal in mm 200	300	400	500	600	700
300	6,3					
400	8,6	12,4				
500		15,7	20			
600			25	31		
700				36		
800					49	
900						64

TABLE "E"
Large panel (for cabinet mounting)
Fixing centres

Vertical en mm	Horizontal in mm 200	300	400	500	600	700
580	13	20	27	34	41	48
880	18	28	38	48	58	68
1 180	23	36	49	62	75	88
1 480	28	44	60	76	92	103
1 780	33	52	71	90	109	128

TABLE "C"
Plates for mounting on uprights
Equipment area > 68.7 dm²

l	h	Useful area dm²	Référence*
200	120	2,1	AM1-PA 0620
200	180	3,1	AM1-PA 1220
200	**360**	6,2	AM1-PA 3020
300	120	3,3	AM1-PA 0630
300	180	4,9	AM1-PA 1230
300	**360**	9,8	AM1-PA 3030
300	**660**	18	AM1-PA 6030
400	120	4,5	AM1-PA 0640
400	180	6,7	AM1-PA 1240
400	**360**	13,4	AM1-PA 3040
400	**660**	24,6	AM1-PA 6040
400	**960**	35,7	AM1-PA 9040
500	120	5,7	AM1-PA 0650
500	180	8,5	AM1-PA 1250
500	**360**	17	AM1-PA 3050
500	**660**	31,2	AM1-PA 6050
500	**960**	45,3	AM1-PA 9050
600	120	6,9	AM1-PA 0660
600	180	10,3	AM1-PA 1260
600	**360**	20,6	AM1-PA 3060
600	**660**	37,8	AM1-PA 6060
600	**960**	54,9	AM1-PA 9060
700	120	8,1	AM1-PA 0670
700	180	12,1	AM1-PA 1270
700	**360**	24,2	AM1-PA 3070
700	**660**	44,4	AM1-PA 6070
700	**960**	64,5	AM1-PA 9070

* Each mounting plate is supplied with 4 washers.
l: mounting plate fixing centres,
h: overall dimension of the mounting plate.
The figures in bold type indicate the plates which, when assembled in pairs, form the five heights corresponding to the heights of the uprights of Telemecanique standard cabinets.

MOUNTING OF EQUIPMENT

Once the space requirements and the type of frame have been decided upon the mounting system for each of the three possible solutions is chosen:

Equipment for pre-slotted mounting plates, maximum dimensions 960 x 734 mm

The pre-slotted mounting plate does not require treatment and is ready for use.
Components are fixed by clip nuts of appropriate size which need only be inserted and positioned from the front of the panel in the slots provided.
Twenty sizes of mounting plates are available to build up the panel vertically or horizontally with a useful area of 2.1 to 68.7 dm^2.

Equipment on small frame, maximum dimensions 900 x 700 mm

A frame mounted panel is constructed by means of:
— pre-drilled uprights,
— DIN mounting rails designed to accept sliding clamps used to fix components,
— pre-slotted intermediate plates, when necessary,
— captive nuts and fixing screws with captive washers for mounting.

Equipment on large frame, maximum dimensions 1,920 x 3,150 mm

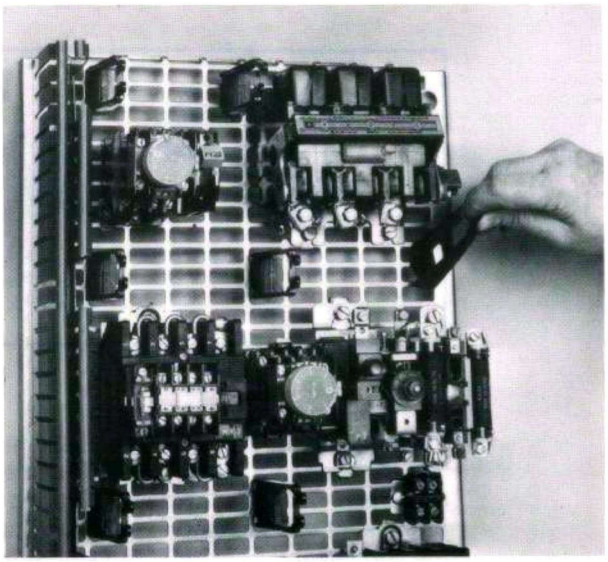
The principle is identical but the uprights and horizontal rails, forming the framework, are stronger. Panels thus constructed can be fitted as above with DIN mounting rails or "TELEQUICK" pre-slotted mounting plates.

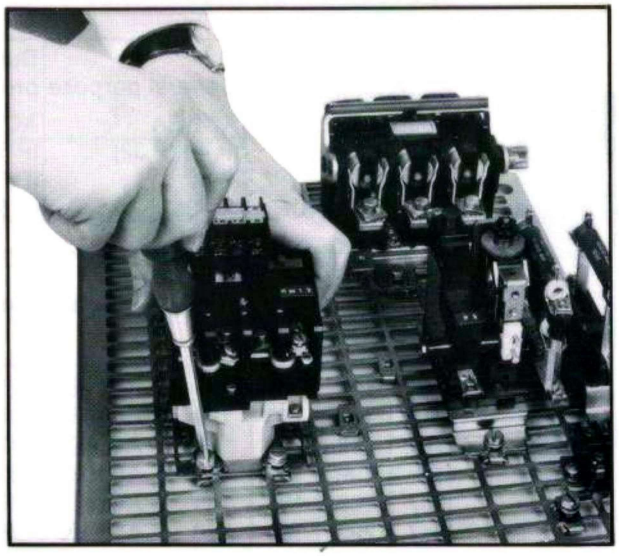
PREPARATION FOR WIRING

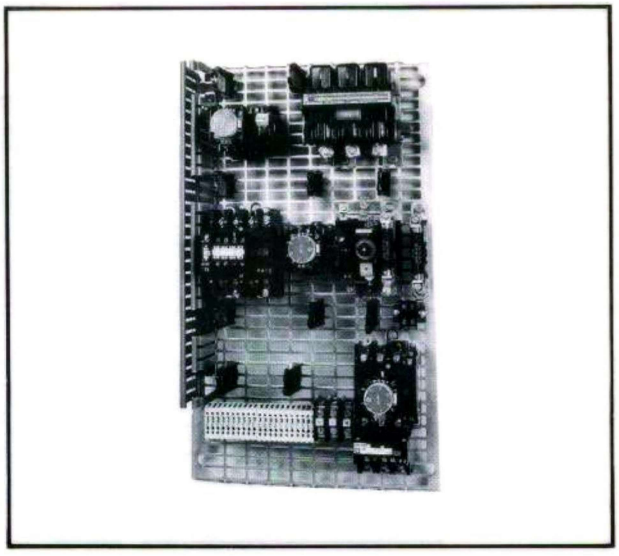
Panel wiring is simplified by the use of cabling accessories to channel the wires into horizontal and vertical bundles adjacent to the components mounted on the plate or rails. Cabling is easily carried out from the front without detracting from the appearance of the equipment and repairs or modifications are also simplified.

Equipment on mounting plates

Wires are routed horizontally and vertically through cable clips of polymide which clip into the slots of the mounting plate after which covers snap onto the cable clips to form a neat frontal appearance.





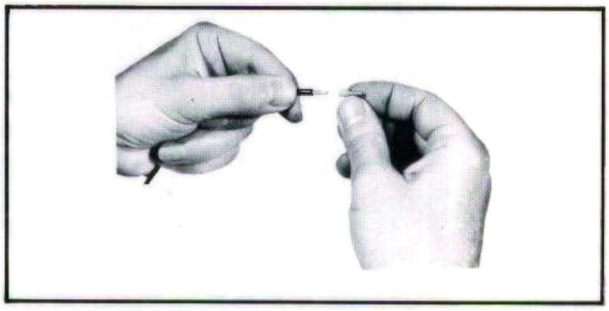


Equipment on frames

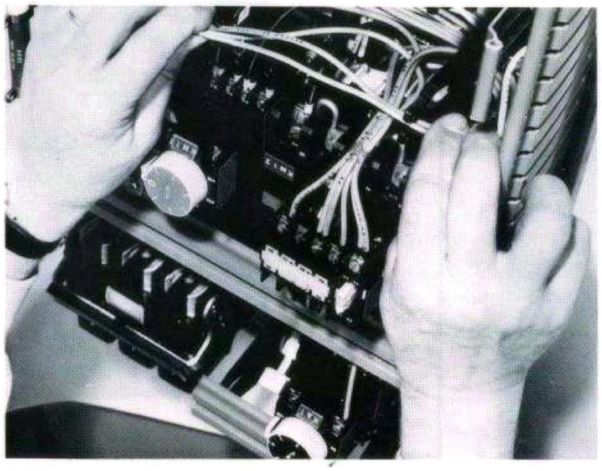
Extruded trunking of vinyl chloride are used for vertical cable runs, slots being provided for easy access. The trunking is clamped on to the uprights and no drilling is required. For panels using DIN mounting rails, wires are channeled horizontally through cable clips which clip in between these rails.

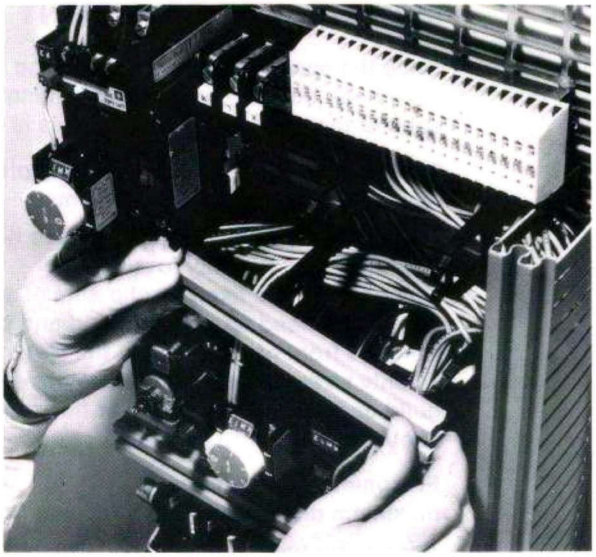
CABLING

After cable trunking and clips are fitted the wiring may proceed. With a wire cutting and stripping tool, produced by Telemecanique, the wire is cut to the suitable length and stripped simultaneously at the two ends resulting from the cut.



Since the conductor is stripped automatically to the length required a Telemecanique cable end is fitted over each end of the wire and crimped by the terminal of the equipment. When wiring is complete the vertical and horizontal trunking are enclosed by a cover cut to the proper length.





PANEL PROTECTION

All equipment can be mounted easily and quickly in metal or insulated enclosures or in cabinets with 1, 2, 3 or 4 doors designed to resist the severest conditions encountered in industrial applications.

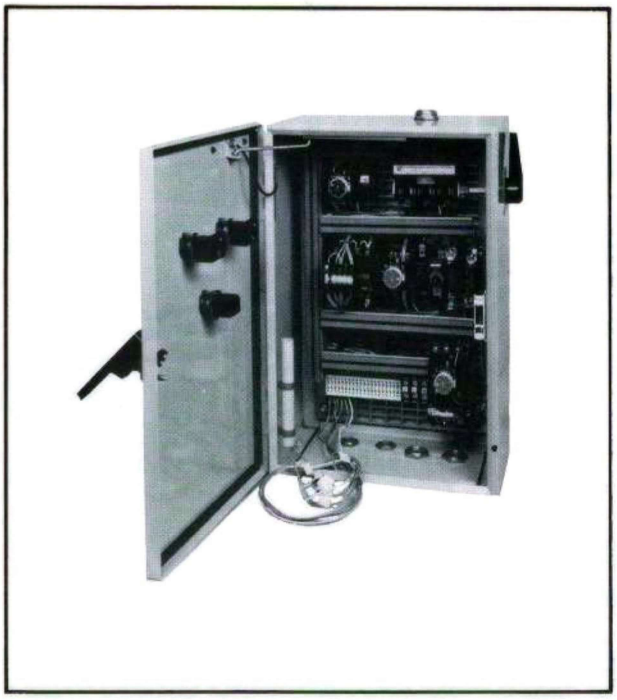
Insulated enclosures DE1-S of fibre glass reinforced polyester for high shock resistance are recommended for applications calling for double insulation and where resistance to corrosive environments is required.

It is only necessary to calculate the panel area and take the enclosure or cabinet with the next higher useful area. These areas are shown in the following tables.

PRESSED STEEL ENCLOSURES

Conforming to standards:	General purpose	Dust and damp-proof type
	AC1-EA	AC1-EB
DIN 40.050	IP 43 (P 32)	IP 55 (P 44)
IEC 144	IP 43	IP 55
UTE C 20-010	IP 435	IP 559

H	L	P	Usable depth p	Reference	Useful area dm^2
284	165	148	135	AC1-EA 281615	3
313	182	150	129	AC1-EB 311815	3
404	180	151	130	AC1-EA 401815	5,6
438	199	151	132	AC1-EB 442015	5,6
307	262	165	145	AC1-EB 302616	4,2
367	292	190	170	AC1-EB 372919	6,2



1, 2, 3 or 4 DOOR METAL CABINETS

Conforming to standards:

DIN 40.050	IP 54 (P 43)
IEC 144	IP 54
UTE C 20.010	IP 549

H	Number and width of doors	Depth	Reference	Useful area dm²
1200	1 x 800	450	DE6-AH 12 L 8 P 4	68,6
	2 x 600	450	DE6-AH 12 L 66 P 4	96,4
	2 x 800	450	DE6-AH 12 L 88 P 4	137,2
1500	1 x 800	450	DE6-AH 15 L 8 P 4	88,7
	2 x 600	450	DE6-AH 15 L 66 P 4	124,6
	2 x 800	450	DE6-AH 15 L 88 P 4	177,4
1800	1 x 800	450	DE6-AH 18 L 8 P 4	108,9
	2 x 600	450	DE6-AH 18 L 66 P 4	153
	2 x 800	450	DE6-AH 18 L 88 P 4	217,8
2100	1 x 800	450	DE6-AH 21 L 8 P 4	129
	2 x 600	450	DE6-AH 21 L 66 P 4	181,2
	2 x 800	450	DE6-AH 21 L 88 P 4	258

WELDED STEEL ENCLOSURES AND POLYESTER INSULATED ENCLOSURES

Conforming to standards:

DIN 40.050	IP 55 (P 44)
IEC 144	IP 55
UTE C 20.010	IP 559

Welded steel type DE1-GB or DE1-GC*			Polyester insulated type DE1-SB or DE1-SC*			Ref.	Useful area dm²
H	L	P	H	L	P		dm²
300	250	150	—	—	—	2151	3,7
400	250	150	409	258	175	3151	5,3
400	300	200	409	308	225	322	7,4
500	300	200	—	—	—	422	9,6
500	400	250	509	408	275	433	13,8
600	400	250	—	—	—	533	16,4
600	500	250	609	508	275	543	23,1
700	500	250	710	510	275	643	27,4
700	600	300	—	—	—	654	33,4
800	600	300	813	613	335	754	38,7
900	700	300	913	713	335	864	51,0
1000	800	300	1013	813	335	974	63,7
1200	800	300				1174	72,7

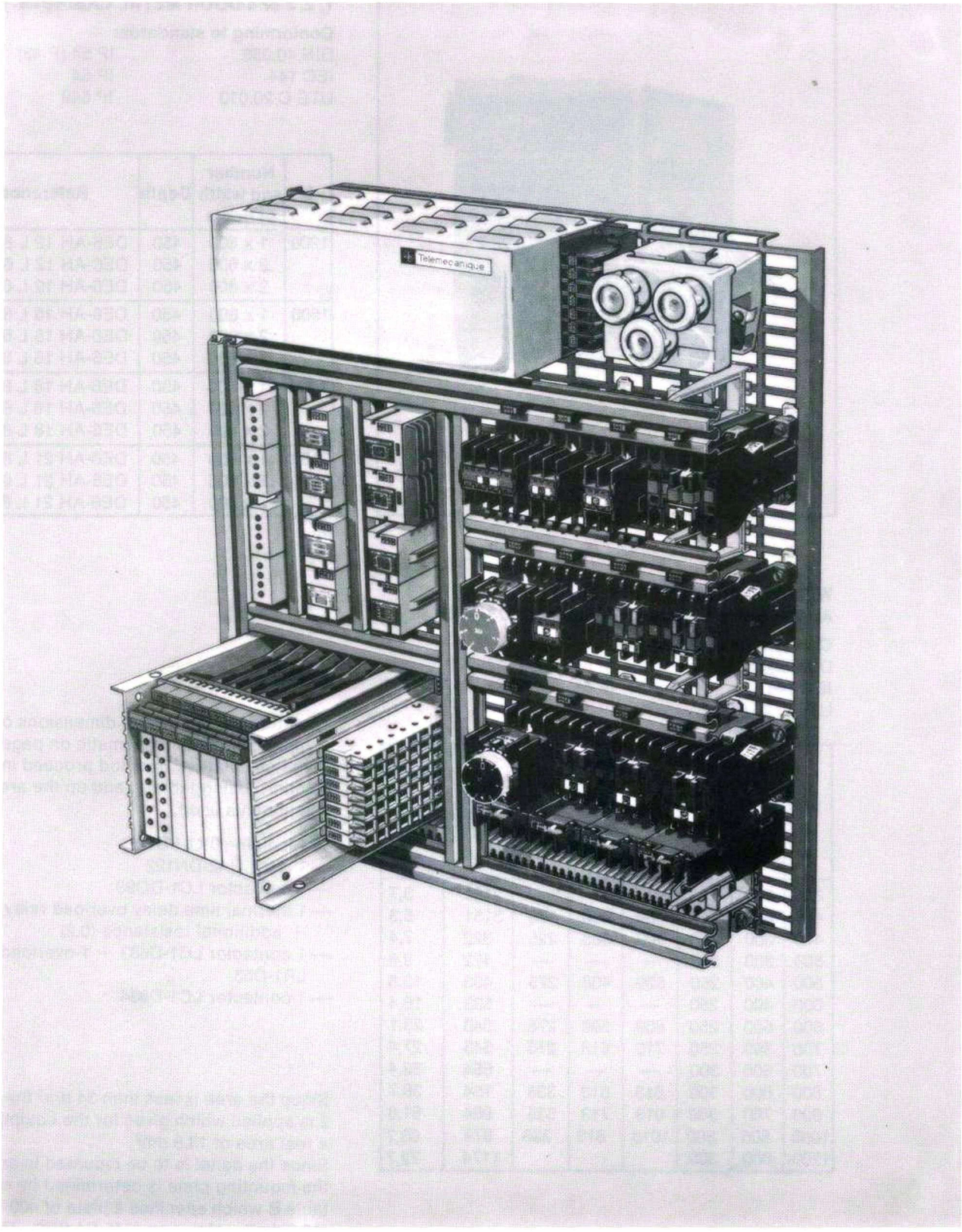
* Enclosures DE1-GC and DE1-SC are supplied with type AM1-PA pre-slotted mounting plate.

EXAMPLE

To determine the overall dimensions of the compressor panel (schematic on page 176) by the "area calculation" method proceed in the following manner. Using table A, add up the areas of the components used.

— 1 isolator DK1-FB13	2.5
— 1 relay CA2-DN122	0.3
— 1 contactor LC1-DO93	0.3
— 1 thermal time delay overload relay RT1-TK + additional resistance (0.2)	1.3
— 1 contactor LC1-D633 + 1 overload relay LR1-D63	1.4
— 1 contactor LC1-D634	1.1
	6.9 dm²

Since the area is less than 34 dm² the factor of 2 is applied which gives for the equipment in question a real area of 13.8 dm²
Since the panel is to be mounted in an enclosure the mounting plate is determined by consulting table B which specifies a plate of 400 x 300 (13.8 dm²), reference AM1-PA4030. Therefore select a steel enclosure DE1-GB433 or an insulated enclosure DE1-SB433.



Panel built using the TELEQUICK system.

This wiring method is especially recommended when the terminals of the panel components are referenced. This is the case for relays, contactors, overload and protection relays, isolators, control auxiliaries and most other products manufactured by Telemecanique (see page 71).
It is applicable for the wiring of the power and control circuits of all automatic control equipment and since the wires do not have to be referenced this wiring method saves the user both time and money.
The circuit diagram (see page 177) offers:
— rapid preparation: appreciable time saving for the draughtsman;
— clarity: simple representation of electrical connections;
— easy interpretation: even for a wireman without special electrical skills;
— efficiency in operation: trouble shooting, modifications and repairs are simplified.
A schematic showing external connections and a layout drawing can also be added when necessary.

wiring of a panel by means of circuit diagrams

WIRING FROM CIRCUIT DIAGRAM

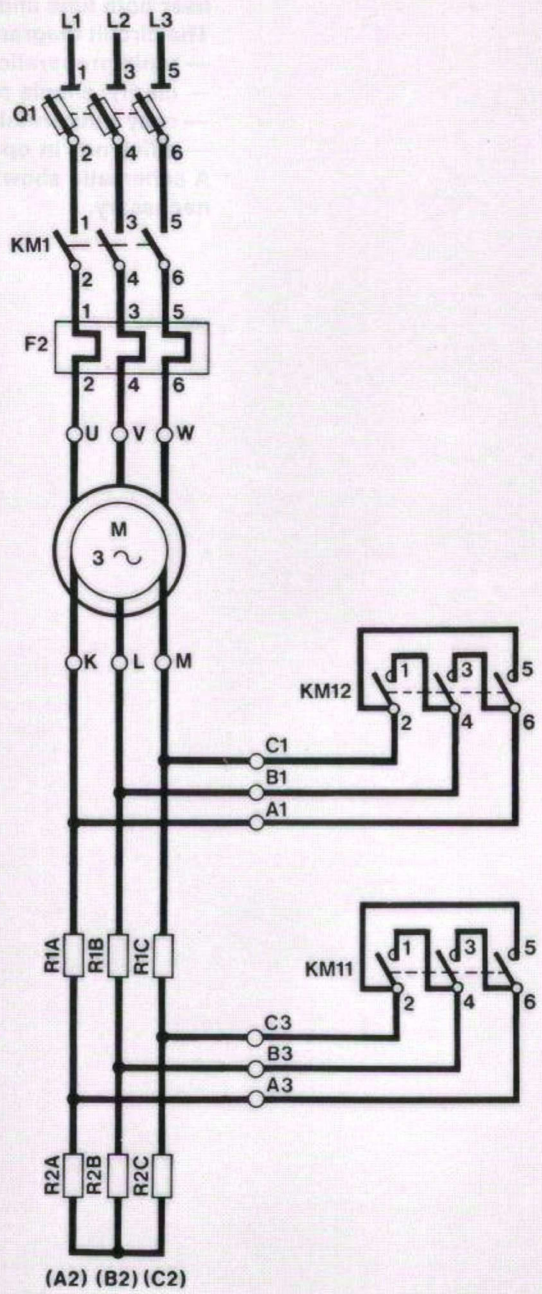
Power connections

The wireman reads the component terminal reference on the circuit diagram and wires between the corresponding references on the equipment.
Example: diagram of compressor equipment, shown on right.
The wireman connects between the terminals:
— L1 of the line and 1 of the isolator Q1,
— 2 of isolator Q1 and 1 of contactor KM1,
— 2 of contactor KM1 and 1 of relay F2,
— 2 of relay F2 and U terminal.
He follows the same procedure for the other two phases.

Control circuit connections

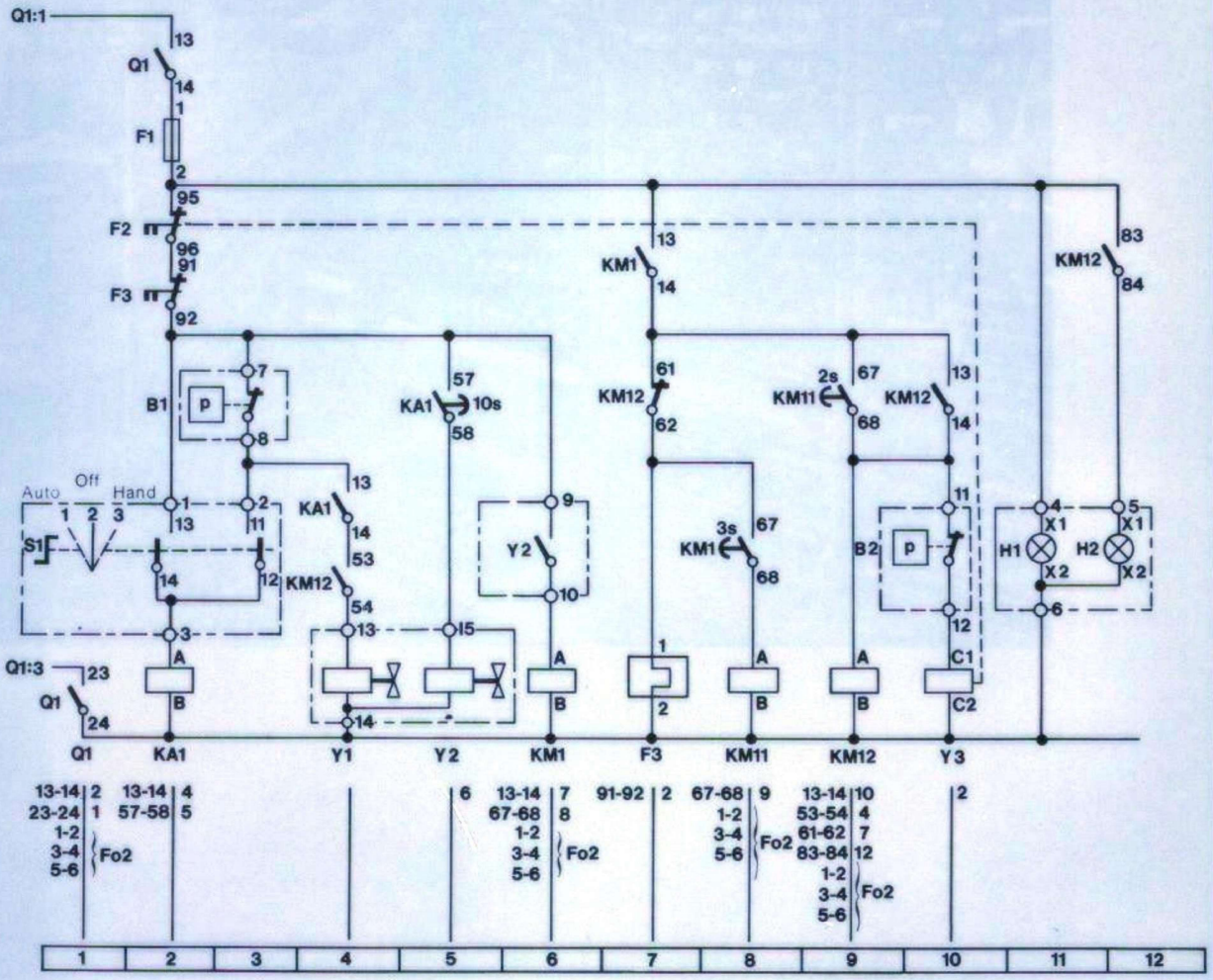
The procedure is identical to the one used to wire the power circuit. Therefore, to wire line 2 the wireman should connect between the terminals:
— 1 of isolator Q1 and 13 of isolator Q1,
— 14 of isolator Q1 and 1 of fuse F1,
— 2 of use 1 and of relay F2,
— 96 of relay F2 and 91 of relay F3,
— 92 of relay F3 and 1 of the terminal block,
— 3 of the terminal block and A of the coil KA1,
— B of the coil KA1 and 24 of isolator Q1,
— 23 of isolator Q1 and 3 of isolator Q1.
He will then go to line 3 and connect:
— 92 of relay F3 to 7 of the terminal block,
— 8 of the terminal block to 2 of the terminal block.
The connections 11, 12, 13, 14 of the selector switch will be made from terminals 1, 2, 3 of the terminal block.

COMPRESSOR PANEL

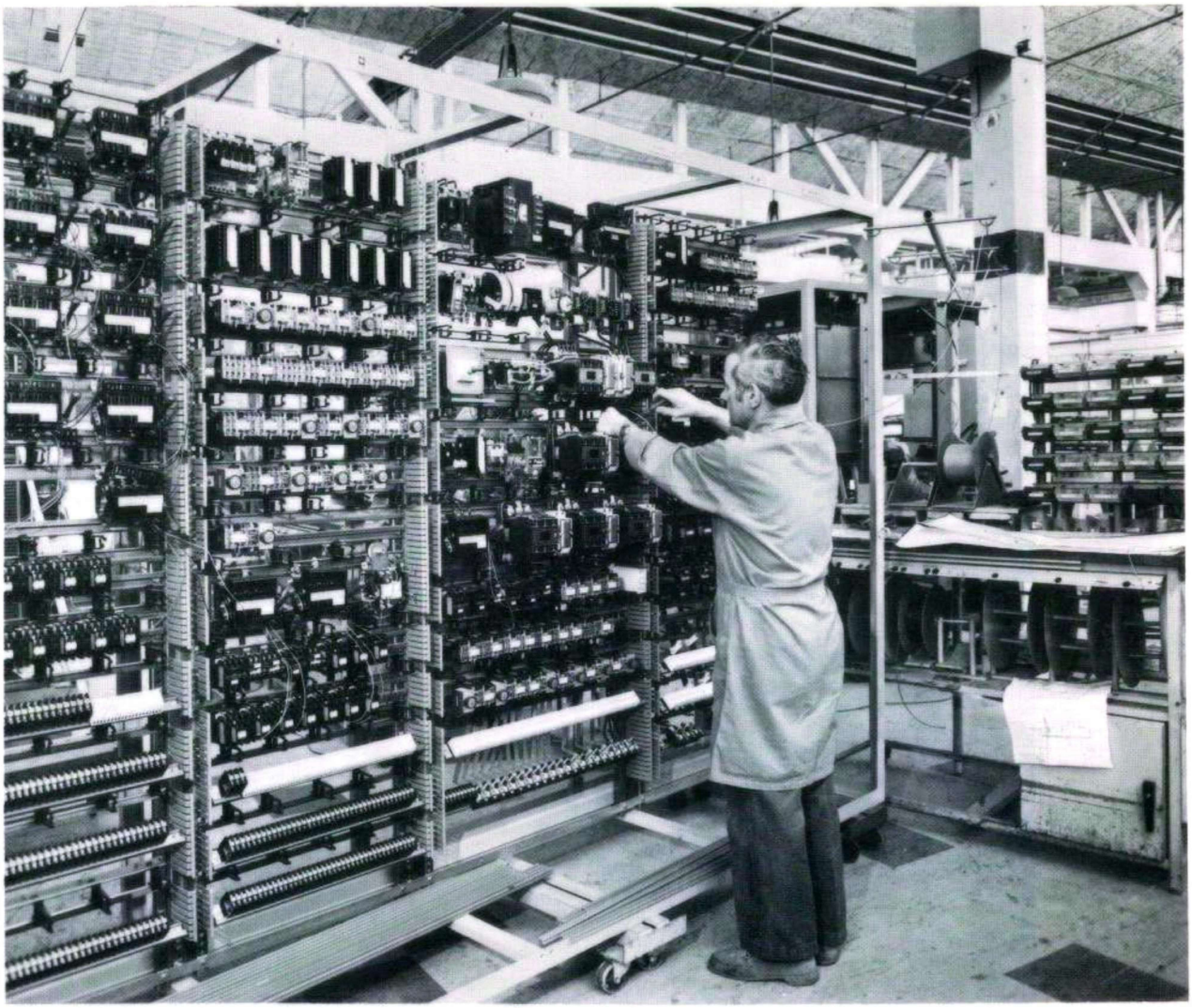


Power circuit

COMPRESSOR PANEL



Control circuit



Before starting electrical tests on the panel it is recommended that all control and power connections be checked to see that they have been properly tightened. The tester will then adjust the tripping current of thethermal overload relays by setting the dial on each relay to the current indicated on the schematic.
The system test will be preceded by a series of tests to make sure that the panel has been wired according to the circuit diagram. The following checks will be carried out for this purpose (circuit diagrams on pages 176 to 177).

CHECKING OF EACH LINE OF THE CONTROL CIRCUIT

In order to carry out no load tests with complete safety the power circuit must be separated from the control circuit so all fuses in the isolator must be removed. The supply line will then be connected to L1 and L2 and when the isolator is closed the supply voltage will be present between terminals 14 and 24 of Q1.
Then a line by line check of the schematic can be started.
Thus, to check line 2 and to close control relay KA1 it is only necessary to link terminals 1 and 3 of the terminal block.
If the wiring is correct KA1 will close. If fuse F1 is removed or if we press push button F2 (contact 95-96) or F3 (91-92) this should open, also if contacts 13-14 and 23-24 of isolator Q1 are opened.
To check line 4, contacts 13-14 of KA1 and 53-54 of KM12, connect a lamp between terminals 13 and 14 and terminals 7 and 8. If the wiring is correct the lamp will light when these contacts are closed; the same is true when connection 7-8 is removed. If these tests are satisfactory lines 2 and 4 are wired according to the schematic diagram.
As an illustration let us check line 8.
The line is available between terminals 14 and 24 of isolator Q1; close contact on contactor KM1 to cause the closing of KM11. To check this open contact 61-62 of KM12. The time delay indicated for the contact of KM1 on the schematic can be set during this operation. For added safety check to see that no error has been made on the load side of contacts 95-96 of F2 and 91-92 of F3 by opening them. There should be no effect.

CHECKING OF THE POWER CIRCUIT

Line voltage disconnected

As in the case of the control circuit this check will prove whether the power circuit wiring conforms to the schematic. Since the tester does not usually have motors available the test will be carried out with a test lamp in the following way.
Connect the test lamp between terminals:
— L1 and U; with the isolator closed manual closing of contactor KM1 should cause the lamp to illuminate;
— L2 and V, L3 and W; manual closing of the contactor will also cause the lamp to illuminate.
The same will be true when closing contactor KM12, with the test lamp connected between terminals K and L, then L and M and finally K and M.
The circuit of contactor KM11 will be checked in the same way.

SYSTEM TEST

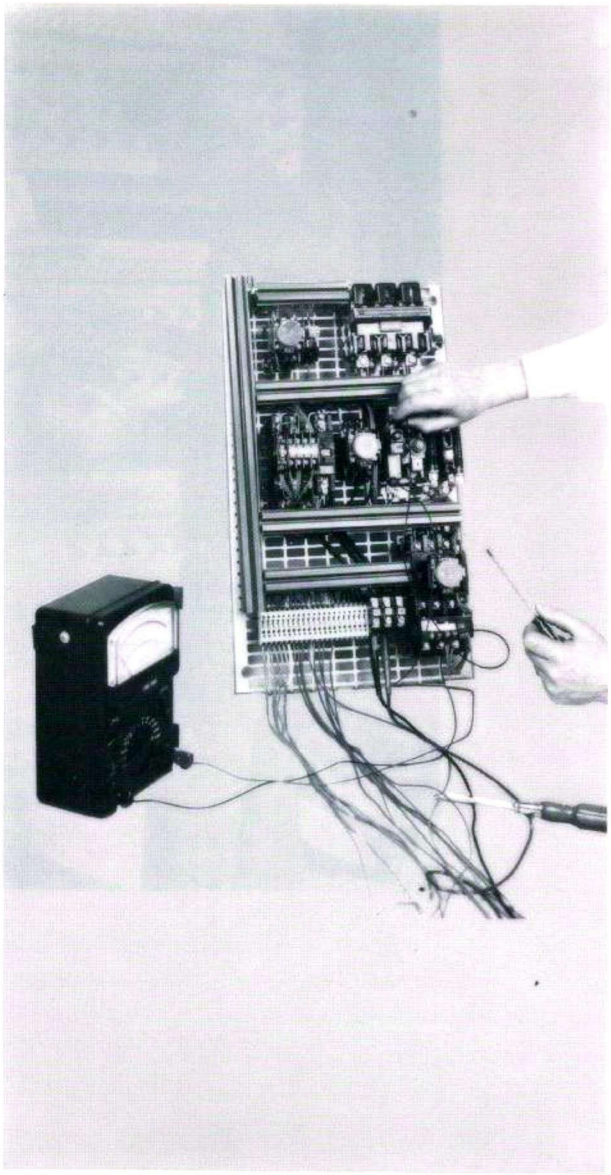
At this point, if all of the above mentioned checks have been carried out and any wiring errors have been corrected, the wiring corresponds to the schematic.
Now make the following connections:
— the "HAND OFF AUTO" selector switch between terminals 1, 2 and 3;
— a switch between terminals 7 and 8 (AIR pressure switch);
— two test lamps across terminals 13-14 (AIR solenoid valve) and 15-14 (WATER solenoid valve);
— a switch between terminals 9-10 (WATER solenoid valve contact) and 11-12 (OIL pressure switch).
and proceed with the system test as follows:

Manual operation

With the isolator closed, the selector switch in the "HAND" position, contacts 95-96 of thermal overload relay F2 (1) and 91-92 of F3 (2) closed the control relay KA1 closes and prepares the supply to the AIR solenoid valve Y1 (contact 13-14).

Time delay contact 57-58 (which closes instantly in this direction) authorizes the supply of the WATER solenoid valve Y2 whose contact causes the closing of contactor KM1. The compressor motor starts.
With contacts 13-14 of KM1 and 61-62 of KM2 closed, the bimetallic element of the thermal relay F2 is energized and 3 seconds later the time delay contact 67-68 of KM1 closes contactor KM11 which shorts out the first section of the resistance inserted in the rotor circuit of the motor which accelerates.
Two seconds later contactor KM12 closes (contact 67-68 on KM11). The starting cycle is completed.

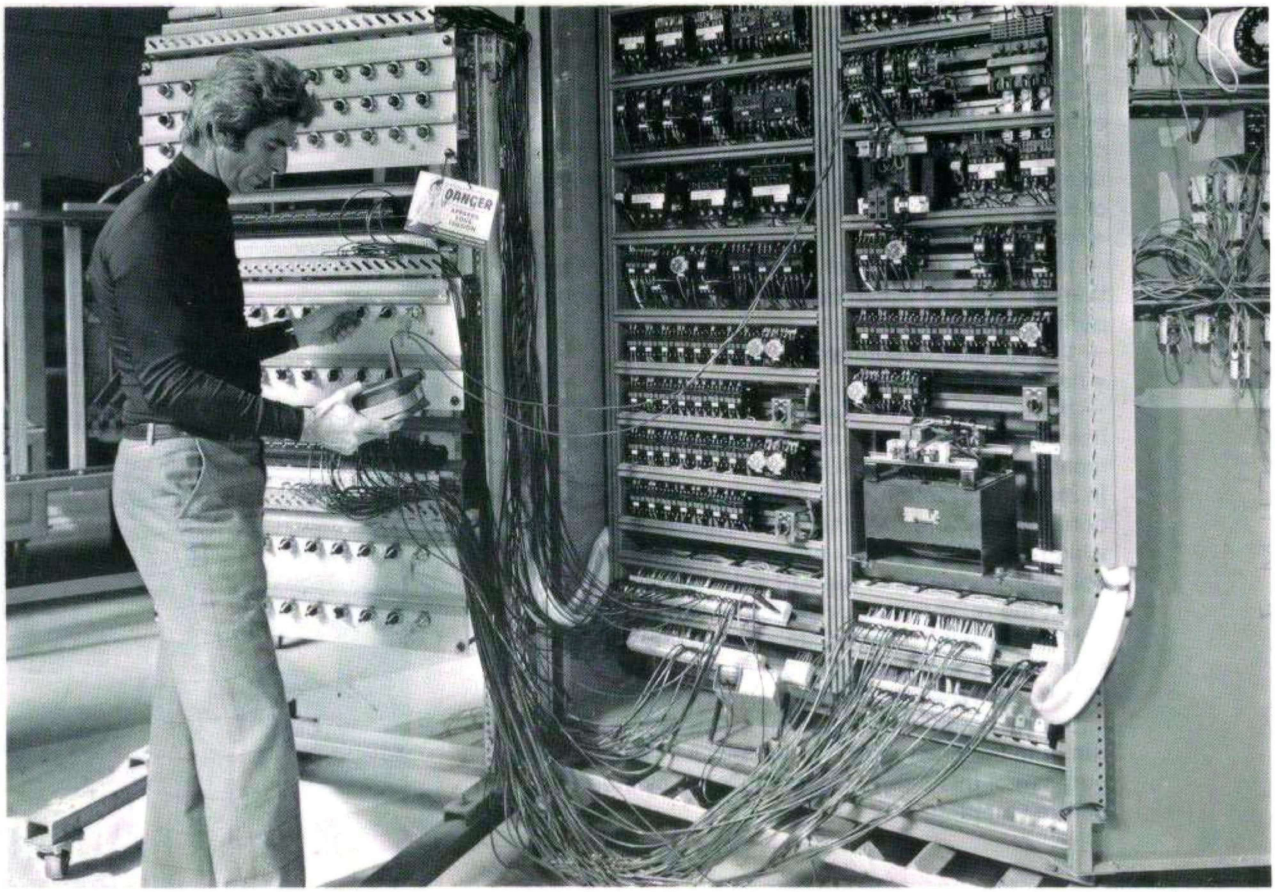
Contactor KM12 causes through:
• its contact 13-14:
— its hold in
— in case the oil pressure is not normal, the energizing of the remote tripping device Y3 mounted on relay F2, contact 95-96, causing the opening of relay KA1 thus stopping the compressor (opening of KM1).
• its contact 61-62:
— the de-energization of the bimetallic strip of the thermal relay F3 which has controlled the starting period.
— the opening of contactor KM11.
• its contact 53-54:
— the energization of the AIR solenoid valve (Y1), itself slaved to the air pressure switch B1 which monitors the tank pressure.
In manual operation, the compressor motor runs continuously and only the AIR pressure switch, which monitors the tank pressure, causes the opening or closing of the AIR solenoid valve (Y1). When the rotary selector switch is moved to STOP, control relay KA1 immediately opens and the AIR solenoid valve is no longer energized (contact 13-14); the WATER solenoid valve Y2 remains energized and the compressor motor continues to run until the time delay contact of KA1 opens. The purpose of this delay is to exhaust the cylinders before stopping.



Automatic operation

In this position, contact 11-12 of the rotary selector switch is closed. Operation is identical to that described above but the AIR pressure switch B1 controls not only the closing or opening of the AIR solenoid valve (Y1) but also the starting or stopping of the motor.
Actually, in the "auto" position, the switch contact 11-12 prepares only the closing of relay KA1; it is the AIR pressure switch B1 which actually closes it and, as in manual, starts the motor. Conversely, the opening of the AIR pressure switch immediately de-energizes relay KA1 and the AIR solenoid valve (Y1). As in "manual" operation, de-energization of the WATER solenoid valve and the stopping of the motor are timed.

(1) On the thermal overload relay F2 a remote tripping device is mounted coupled to contact 95-96.
The coil Y3 of this device is in series with the pressure switch which opens when oil pressure is sufficient.
(2)The thermal relay F3 protects the starting resistances against incomplete or too frequent starts.



Panel under test

All equipment leaving our factories has been checked thoroughly by qualified technicians before shipment. Each item has been set or carefully calibrated with the highest accuracy. Modifications of settings should be avoided except in the case of overload relays.

putting equipment into service

WHEN EQUIPMENT IS RECEIVED

- make sure that heavy shocks have not damaged the equipment;
- on bar and shaft contactors in particular, check that the moving part has not been bent or displaced;
- check that foreign particles have not been lodged in the air-gaps of the magnetic circuits or between the contacts;
- make sure:

— that the moving part of contactors and isolators, as well as the tripping devices of overload relays, operate freely;
— that locks (on enclosures or cabinets) function properly;
— that seals are effective (for airtight equipment);
— that schematics and operating instructions have been included with the equipment;
— that pilot devices and metres are in good order.

BEFORE CONNECTING EXTERNAL CONDUCTORS

Before connecting the main supply:

- make sure that the voltage and frequency of the main supply corresponds to that indicated on the contactor coils;
- check that the type and size of the fuses and protection relays are matched to the load to be protected. In the case of a star delta starter, when the overloads are connected in series with the motor windings, the value to which the relays should be Set is $\frac{I}{\sqrt{3}}$ where I is the motor current

FIXING AND CONNECTING EQUIPMENT

- fix the equipment firmly on its support;
- determine the cross section of incoming cables in relation to load current. In order to avoid voltage drops, increase the cross section of cables supplying the control and power circuits when the line is long or when the control circuit operates at low voltage;
- on panels equipped with cable glands, the conductor insulation should be inserted into the rings of the gland. When tightened the gland supports the insulation and all stresses are taken by the gland and not by the connecting terminals of the components;
- when making external connections, follow the schematic with extreme care;
- do not fail to respect all relevant installation rules. To this end a referenced terminal is provided on enclosures, cabinets and many components for the connection of a common earth;
- for equipment used in especially corrosive or tropical environments, the application of a coat of insulating varnish is recommended on terminals in order to protect against corrosion.

SETTING OF THERMAL OVERLOAD RELAYS

The graduations of the dial in amperes correspond directly to the motor current.
Conforming to standards IEC 292-1 and UTE 63-650 (1), these relays trip at values of between 105 and 120% of the set current. This is obtained by setting the pointer to the value marked on the dial which corresponds to the motor current (read on the rating plate the full load current corresponding to the main supply voltage). Since these relays are compensated, no correction is needed for ambient temperature variation within the limits specified on the data sheets.

SYSTEM TEST

With the main supply and all external power and control circuits connected in accordance with the schematic, a systems test of the equipment can be carried out. This can be done in two steps:

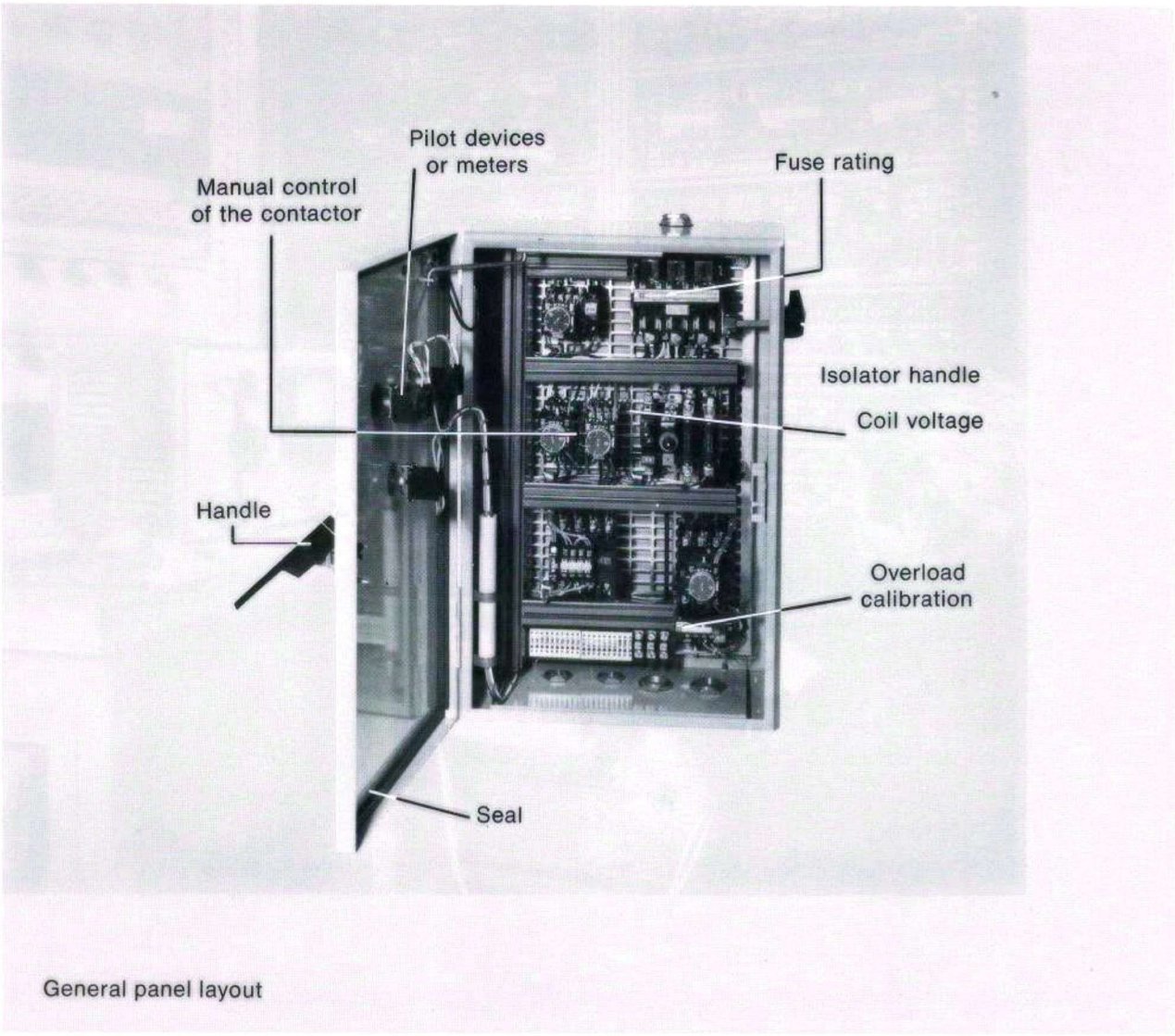
Off load test

The purpose of this test is to verify that all external control, protection and signalling components have been correctly conected. To carry out the test, the supply to all loads must be isolated:
— either by removing the fuses protecting the power circuit;
— or by placing the isolator in the test position.
With the control circuit live, operating the pilot device which authorizes starting should cause the closing of the main contactor and, on more complex equipment, the operation of the cycle as specified in the schematic diagram described in the operating manual.
At this point, it is recommended that the external safety devices are simulated and all the possible control and operating malfunctions are tested. This will permit the effectiveness of the control circuit to be checked as well as the sequence control, safety and signalling circuits.

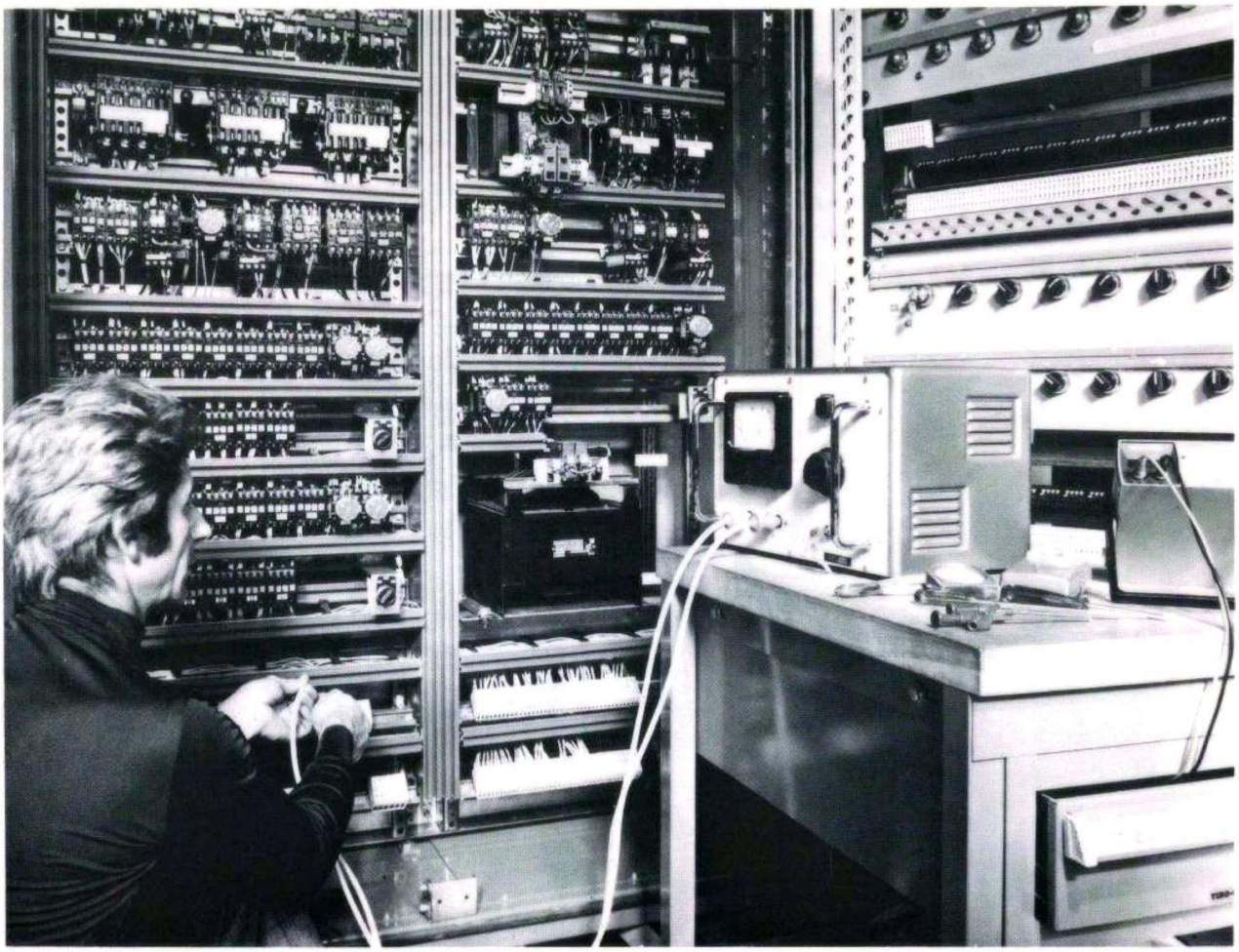
On load test

With the main circuit live, a system test identical to the preceding one should be carried out in order to check connections and the operation of the various loads.

(1) U.T.E. NFC 63-650 (July 1969). Starters for electric motors.



General panel layout



Given the wide variety of automatic control equipment which can be produced using Telemecanique components it is not possible to define a trouble shooting method which can be followed to the letter and which is applicable to all schemes. Nevertheless, as an illustration we shall describe the method which woud be used to trouble shoot the compressor equipment whose schematic is shown on page 177.

equipment trouble shooting

PRELIMINARY CHECKS

Regardless of the type, size and complexity of the equipment, a certain number of checks should be carried out before proceeding with a detailed examination.
First of all, check for the presence of voltage at the incoming terminals using a test lamp or meter.
• If the equipment contains an isolator:
check to see that it closes correctly and that its auxiliary contacts are firmly closed.
• If the equipment contains fuses:
make sure that the control circuit fuses have not blown.
• If the equipment includes overload relays:
check that all the relays are set (the relays are reset by pressing the red push button located on the relay).

TROUBLE SHOOTING

After all preliminary checks have been carried out, if:
• The control relay KA1 does not close when the selector switch is turned to "HAND", connect a test lamp or meter across the coil. Two cases are possible:

There is no voltage:

— switch the equipment off;
— check the tightness of all terminals and the continuity of the selector switch contacts;
— also make sure that no connection is broken;
— with a battery operated test lamp check the continuity of the control circuit operating from the load side to the supply side at all points in the circuit.

The voltage is normal:

— check that the voltage indicated on the coil is the same as that measured on the meter;
— make sure the coil connections are tight;
— change the coil if necessary.
• The contactor is energized but does not close completely:
— the contactor has been subjected to a mechanical shock which has damaged the moving part or else foreign matter has lodged inside the magnetic circuit.
To detect this fault just move the armature manually with equipment switched off:
— the main supply voltage is too low;
— the coil is not matched to the actual voltage of the main supply;
— the length of the control cables or their insufficient cross section creates too large a voltage drop at the moment the armature of the magnetic circuit pulls in.

• Relay KA1 closes but the contactor KM1 remains open:
— check the condition of contact 57-58 of KA1, the coil of the solenoid valve Y2 and the contact in the valve.
• Contactor KM1 closes but the motor stops during starting:
— make sure that the thermal overload relay is correctly rated for the motor current (otherwise 95-96 of F2 has opened);
— see if the starting of the motor does produce a large voltage drop in the supply line (voltage insufficient to permit the closing of KM11 and KM12 and tripping of F3);
— starting time too long or too frequent which cause the tripping of the thermal relay F3 (opening of contact 91-92).
• At the end of starting the motor stops:
— contactor KM12 has not closed therefore with contact 61-62 of KM12 closed, relay F3 has remained energized and has caused the opening of contactors KA1 and KM1 (opening of contact 91-92);
— contact 13-14 of KM12 has closed but the oil pressure being insufficient the pressure switch contact remains closed. The coil of the remote tripping device Y3 is energized and causes the opening of contact 95-96 of F2.
When the equipment is more complex the schematic should be carefully examined and divided into elementary schematics, each corresponding to a well defined function of the equipment which can then be checked out methodically.
Thus, on the compressor schematic on page 177, if contactor KM11 does not close it is only necessary to check the circuit which energizes its coil and especially the condition of contacts 13-14 of KM1, 61-62 of KM12 and 67-68 of KM1.

equipment maintenance

CONTACTORS

The contactors manufactured by Telemecanique require practically no maintenance. Nevertheless, we have indicated below a few important points concerning:

THE ELECTROMAGNET

If a magnetic circuit vibrates, check:
— the voltage of the main supply. An electromagnet vibrates when it is operated at a voltage lower than that for which it was designed;
— that no foreign matter is lodged between the moving and fixed parts of the armature;
— the condition of armature surfaces. These should never be painted, scraped or filed. If they are particularly dirty clean them with trichlorethylene.

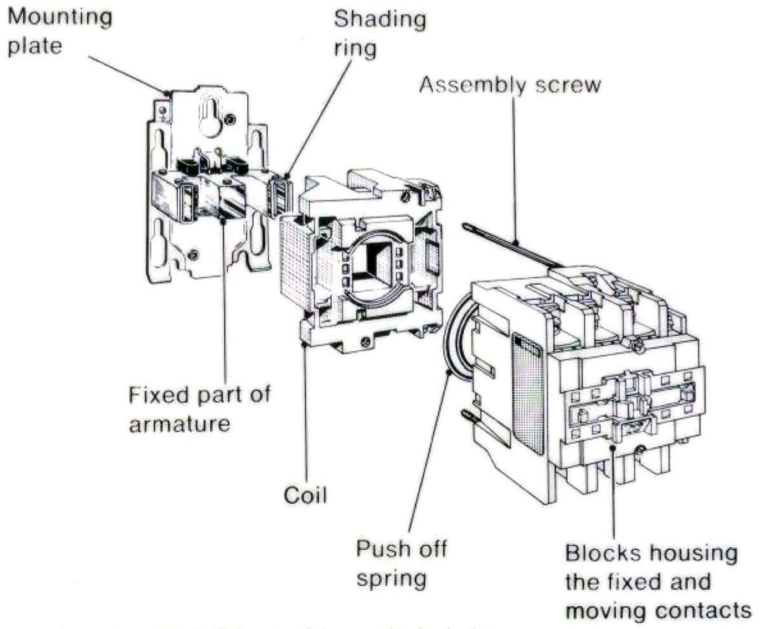
COIL

If it becomes necessary to replace a coil, in case the control circuit voltage is changed for example, the following points must be taken into account:
• the coil of a contactor must be chosen in relation to the actual supply voltage of the control circuit. This permits:
a) closing of the contactor when the control circuit voltage reaches 85% of its rated value;
b) opening of the contactor when the control circuit voltage drops below 65% of its rated value;
c) withstanding continuously a voltage corresponding to 110% of the rated value.

A coil can be damaged by:

• Incomplete closure of the armature as a result of mechanical problems or of a control circuit voltage lower than the value specified in "a". On a.c. this results in a reduction of the reluctance of the magnetic circuit and on d.c. inefficiency of the economy circuit in which the contact has not opened.
Another result is insufficient pressure on the poles which heat up abnormally and which may weld together if the current flowing is that of the motor during starting.
• A supply voltage higher than the value specified in "c".
In every case the coil is damaged because the energy dissipated by the heating effect is higher than normal. In order to avoid such risks the coils used should be matched to the voltage measured at the equipment terminals.

Contactor LC1-D40; D63



The moving part of the armature is not visible on this exploded view.

POLES

Knowledge of the power controlled and the duty category is used to determine the service life of the contacts or to select a contactor as a function of the required number of switching operations.

These contacts properly adjusted can continue to work without any problem.

Wear too advanced - it is time to change these contacts.

D range contactors

The poles of the D range contactors require no maintenance.
For example, in category AC3, a contactor supplying the motor of a compressor starting 6 times per hour and operating 24 hours per day will have a service life of:

$$\frac{2{,}500{,}000}{6 \times 24} = 17{,}360 \text{ days}$$

or about 50 years without maintenance.

Bar and shaft contactors
Current rating $\geqslant$ 80 A
Replacement of main contacts:

Only a periodic check of compression travel (refer to page 10) can reveal the degree of wear. During the period of use never try to adjust the compression travel.
On the other hand when this value is below 50% of the initial value, replace the contacts.

After every change of contacts:

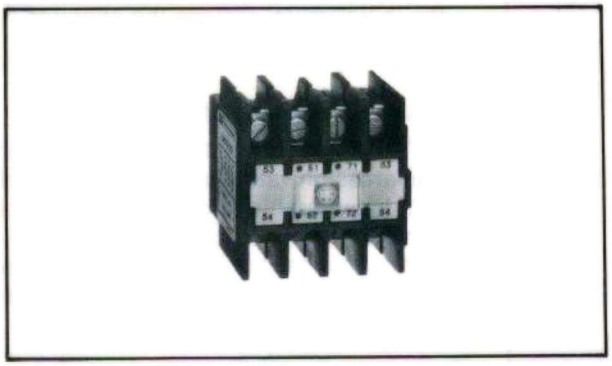
— The contacts must be aligned, adjusting the initial compression value (see specific data sheets).
— It is preferable to check the pressure of each contact.
— Arc shields should be scraped clean internally.
— It is essential to check the tightness of setting screws and nuts.

Contactor CN1-J

Contactor LC1-D

AUXILIARY CONTACTS

No maintenance.
Do not modify the travel of auxiliary contacts - this has been determined by the contact function (hold in, sequence control, economy resistor switching, signalling...).

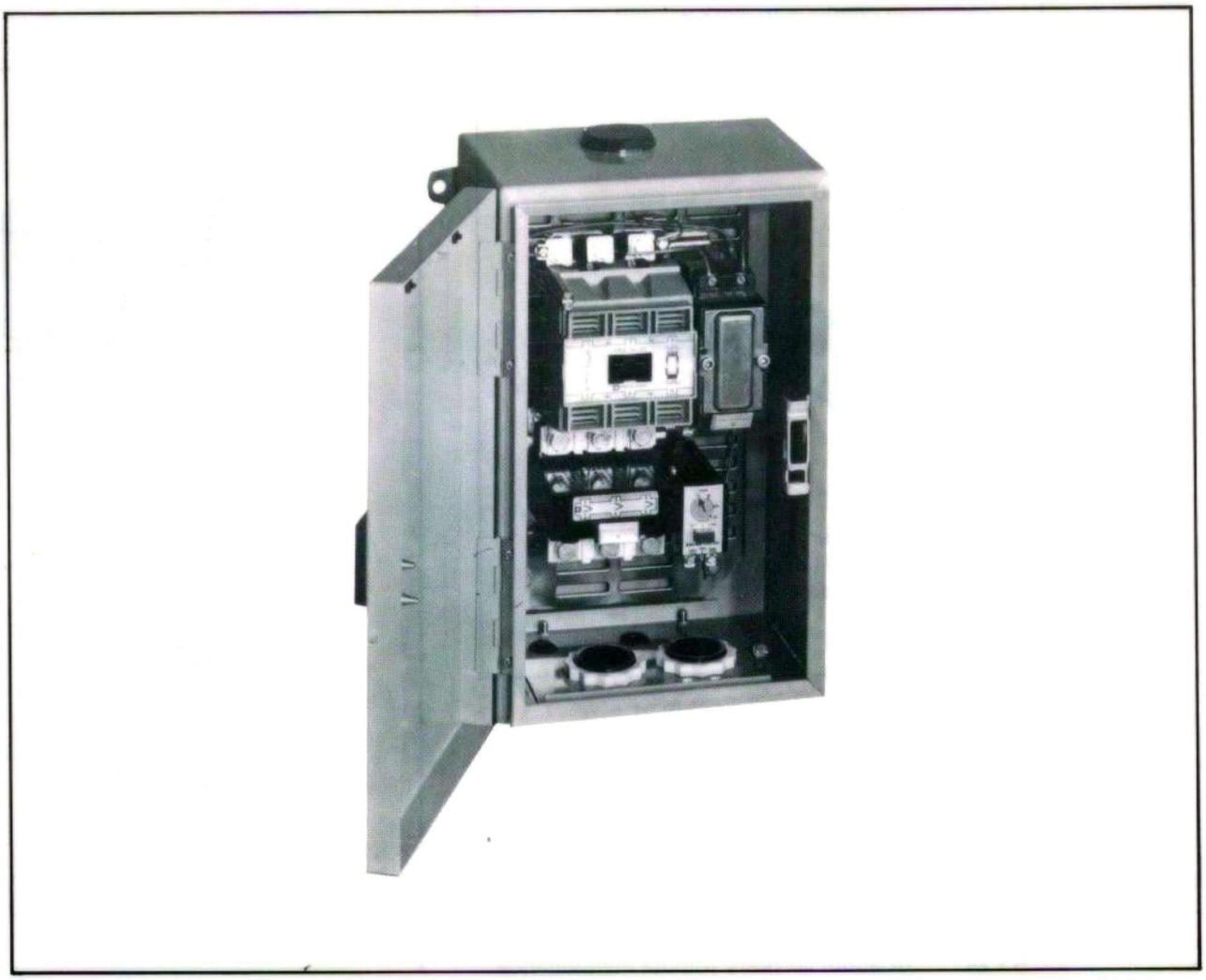


ENCLOSURES

Periodically lubricate hinges and locking devices.
On airtight enclosures, check the condition of the sealing devices (compression glands, cable box).
Check the condition of gaskets.

WHAT SHOULD NOT BE DONE:

— File or lubricate contacts.
— Hastily fabricate a make-shift part or replace a part by a poorly matched spare.
— Reset an overload relay without having found and eliminated the cause of the problem.
— After a fuse has blown and been replaced carry out a new test without having corrected the fault.
— Leave an enclosure or cabinet open when not necessary especially in a dusty environment.



information

definitions and comments

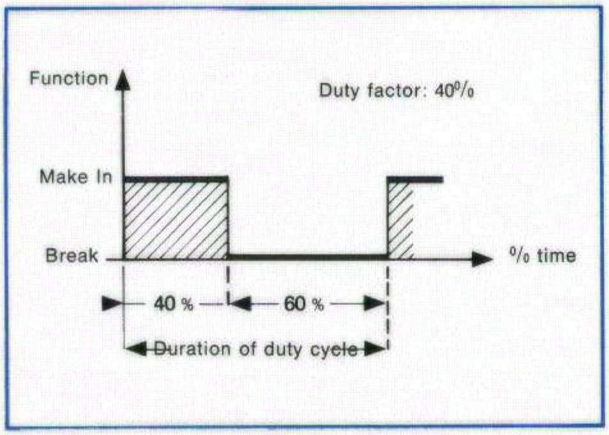
ALTITUDE

The drop in air density with altitude affects the operating voltage of a contactor as well as its cooling capacity and therefore the operating current of a contactor. Telemecanique contactors can be used without derating up to an altitude of 2,000 m (IEC and NF standards).

MAXIMUM SWITCHING RATE

This is the maximum number of operations per hour which can be required of a contactor considering a duty factor of 40% (1). A switching rate of 10,800 per hour corresponds to 3 operations per second.

(1) The normal values for duty factor, defined in IEC and NF standards, are 15, 25, 40 and 60%.

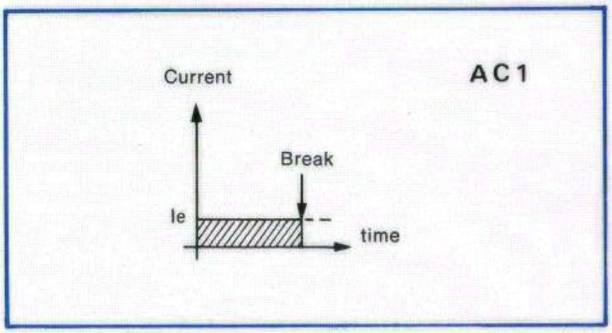


DUTY CATEGORY

The duty category takes into account the current that the contactor must make or break during on load switching operations.
This depends upon:
— the type of circuit: squirrel cage motor, slipring motor, heating, lighting, etc.;
— the conditions under which the contactor breaks: motor running or motor stalled.
The table below summarizes the test specifications corresponding to the normal duty categories.
The three curves illustrate the chart.
Id is the motor starting current and Ie is the running current.

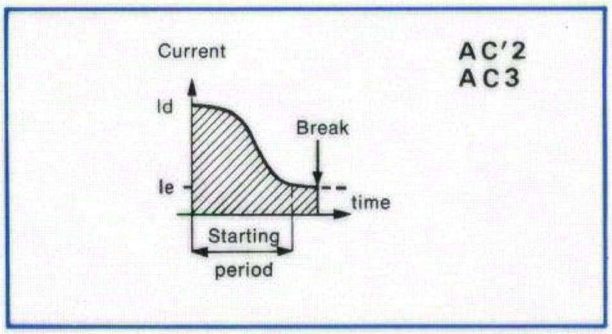
CATEGORY AC1

This applies to all a.c. loads having a power factor of at least 0.95 ($\cos \varnothing \geqslant 0.95$).



CATEGORY AC'2

This concerns slip ring motors with the current being broken while the motor is running. On closure the contactor makes the starting current, in the order of twice the rated motor current. The exact value depends upon the rotor circuit resistance.



Application characteristics	Categories	Making and breaking conditions corresponding to normal operation			
		Making		Breaking	
		I	U	I	U
Resistances (non-inductive loads)	AC1	Ie	Ue	Ie	Ue
Slip ring motors:					
break with motor running	AC'2	2,5 Ie	Ue	Ie	0,4 Ue
break with motor stalled	AC2	2,5 Ie	Ue	2,5 Ie	Ue
Squirrel cage motor:					
break with motor running	AC3	6 Ie	Ue	Ie	0,17 Ue
break with motor stalled	AC4	6 Ie	Ue	6 Ie	Ue

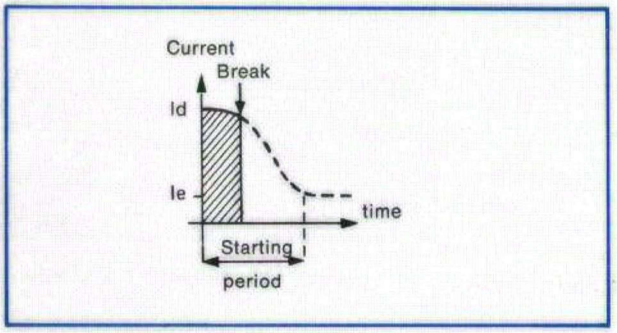
On opening the contactor breaks the rated motor current and the voltage which appears at its terminals is a function of the back e.m.f. of the motor. Light duty breaking is involved.

CATEGORY AC3

This concerns the squirrel cage motor with the current being broken while the motor is running. On closure the contactor makes the starting current which is from 5 to 7 times the rated motor current. On opening the contactor breaks the rated motor current and at this instant the voltage at the terminals is of the order of 20% of the main voltage. In category AC3 the number of switching operations per hour can be high but breaking remains simple. These contactors are also designed to withstand a limited number of breaks of the motor starting current (category AC4).

CATEGORY AC2

This category governs starting, reverse current braking and inching of slipring motors (cos ∅ from 0.3 to 0.7).



On closure the contactor makes the starting current which is in the order of twice the rated motor current.
On opening the contactor breaks the starting current with a voltage at least equal to the main supply voltage; the higher the voltage the slower the motor speed therefore the back e.m.f. is small. The break is difficult.

CATEGORY AC4

This category concerns starting, reverse current breaking and inching of squirrel cage motors.
The contactor closes with a starting current which can reach 5 to 7 times the rated motor current.
On opening the contactor breaks the starting current and the voltage can be equal to that of the main supply. The break is severe.

AVERAGE COIL CONSUMPTION

Average coil consumption is stated at 50 and 60 Hz for pick up of the armature and then for hold in. When the electromagnet is open the impedance of its coil is low and the pick up current can reach 6 to 10 times the hold in current.
The cross section of the supply cable and possibly the transformer capacity, in the case of low voltage control, should be chosen so as to limit voltage drop during pick up.

RATED OPERATING CURRENT

The rated operating current of a contactor is defined on the basis of the rated operating voltage, service, duty category and the ambient temperature around the component.

RATED THERMAL CURRENT

The rated thermal current (Ith) is the current that the contactor is capable of withstanding for a period of eight hours with the main contacts remaining closed for the entire period, with the temperature of its various parts not exceeding fixed limits.

Note: the VDE standard defines also Ith 2 (continuous service - without switching) which approximates to the operating current in AC1.

SHORT TIME RATING

This is the current that a contactor in the closed position can withstand for a short period (from 1 sec to 3 min) without damage to its constituent parts. For the Telemecanique range it is higher than the rated current in category AC1.

ELECTRICAL LIFE

This is the number of switching operations under load that the contactor is capable of without maintenance.
Electrical life depends upon the duty category, the rated operating current and rated operating voltage.

MECHANICAL LIFE

This is the number of no load switching operations that the contactor is capable of without maintenance.

FREQUENCY OF THE CONTROL CIRCUIT SUPPLY

The magnetic circuit is designed to operate on 50 Hz or 60 Hz. However, for a given voltage, the coil should be chosen as a function of frequency. For the usual voltages i.e. 110 and 220 V special coils are suitable for both frequencies (50 and 60 Hz).

Example:
220 volts - 50 Hz: coil LX1-D09 220.
220 volts - 60 Hz: coil LX1-D09 190.
220 volts - 50 or 60 Hz: coil LX1-D09 2206.

FREQUENCY OF THE MAIN SUPPLY

The operating characteristics of the main poles of the contactor are considered for use with a.c. supplies having a frequency of between 25 and 400 Hz.
The use of d.c. or a.c. with frequencies between 400 and 1,000 Hz require special precautions.

STANDARDS AND APPROVALS

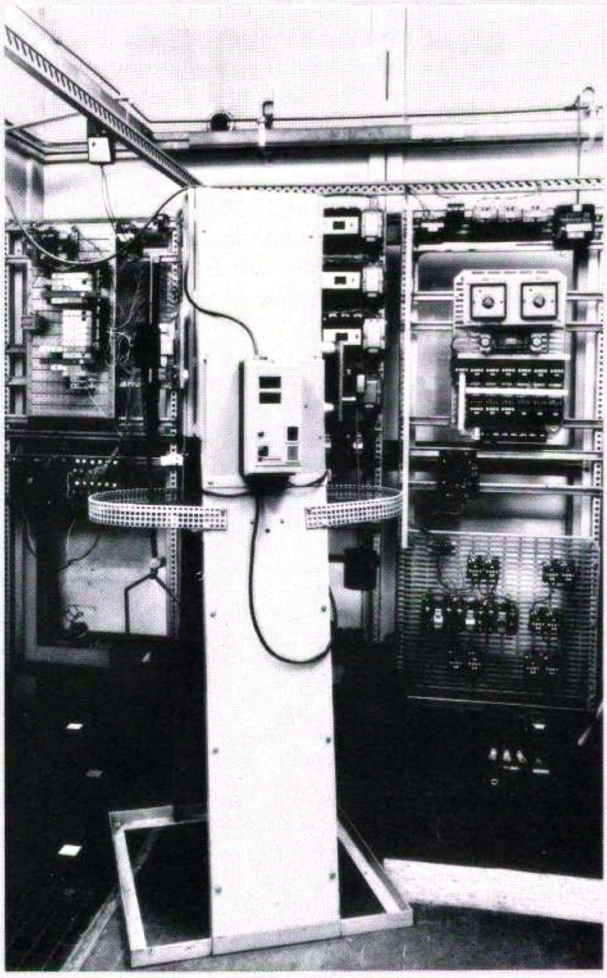
Many countries have set up their own National standards but they are continuing to be harmonized both on the European level (CENELEC) and on the International level (IEC).
Our equipment conforms generally to the specifications mentioned in the publications of these two authorities. It also conforms to the principal corresponding National standards, for example: UTE, DIN, VDE, BS, etc.
In some countries, equipment must undergo special tests in order to be approved for use (CSA, UL, KEMA, etc.). There are also approvals for certain special uses i.e. for marine use Bureau Véritas, etc.
Much of our equipment has undergone these approval procedures and our Branch offices can supply further information.

OPERATING POSITION

Normally components are mounted in the vertical plane. However our contactors are capable of operating when tilted up to 22°30 in any direction with respect to the normal position which is a requirement of Naval organizations: the use of certain components at angles in excess of the above is possible.

BREAKING CAPACITY

This is the r.m.s. value of the maximum current the contactor can break. Its value rises as the mains supply voltage decreases. Example: 250 A/380 V; 85 A/660 V for contactor LC1-D09.



Approval testing laboratory and equipment.

MAKING CAPACITY

This is the r.m.s. value of the maximum current the contactor can make. In practice the current is independant of the voltage. Example: 250 A for contactor LC1-D09.

RATED OPERATING POWER

For motor control, in addition to the rated operating current the maximum rated power is given at the rated operating voltage in question.
The power table specifies the contactors to be used in the case of duty categories AC3 (squirrel cage motor) and AC'2 (slip ring motors), breaking after starting. The values are valid without maintenance or replacement of contacts.

AMBIENT TEMPERATURE

This is the temperature of the air in which the component is located.

OPERATING TIME AT Un

Closing time

The figure indicates the time between the appearance of the voltage at the coil terminals and the making of the main poles.

Opening time

The figure indicates the time which elapses from the instant the coil is de-energized until separation of the main contacts. To this time the arc extinction time, about 10 msec, is added. Breaking time is the sum of these two values.

RATED OPERATING VOLTAGE

The rated operating voltage of a contactor is a voltage value which, combined with a rated operating current or rated operating power, determines the use of the contactor and on which the making and breaking capacities, the type of service and duty category are based.

RATED INSULATION VOLTAGE

The rated insulation voltage is the value of voltage which is referred to in dielectric tests determining leakage paths and distances. The specifications are not identical for all standards; the nominal value selected for each of them can sometimes be different. In particular, the insulation distances of our devices are greater than those required by the French standard UTE NF C 20-040 for 500 V and correspond to the nominal insulation voltage of 660 V conforming to IEC. Except in special cases, such as in rotor resistance short circuiting, rated insulation voltage is the maximum value of the rated operating voltage.

DROP OUT VOLTAGE

This is the voltage at which the moving part of the armature resumes its de-energized position.

PROTECTIVE TREATMENT OF EQUIPMENT

Telemecanique offers three treatments; in order to make the proper choice the following points should be taken into account:
- only the atmosphere in the immediate vicinity of the equipment need be considered;
- the prevailing climate is never the only criterion.

"ALL CLIMATES" TREATMENT " TC "

This is the standard treatment for Telemecanique equipment

This treatment is suitable for the large majority of cases. It is equivalent to treatments under other names such as Klimafast, Climateproof, Total Tropicalisation or Super Tropicalisation and meets the same requirements:
Standard DIN 50016.
They also meet the recommendations of the following shipping organizations: BV; LROS; GL; NV; RINA.

Limitations of the use of "All climates" treatment

Continuous operation under relative humidity of:
95% at 20 °C, 80% at 40 °C, 50% at 50 °C;
or if these values are exceeded for short periods;
or if these temperature variations are insufficient to cause condensation on the equipment.
Consequently the "All Climates" treatment is suitable for all latitudes, especially in tropical countries, when the material is located in normally ventilated industrial areas. Actually, when protected from external conditions, temperature variations are small and the risk of condensation is low.

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TREATMENT "TH"

For hot and humid environments

This treatment is recommended for hot and humid environments causing heavy condensation and formation of mildew. In addition the materials used resist insects such as termites.

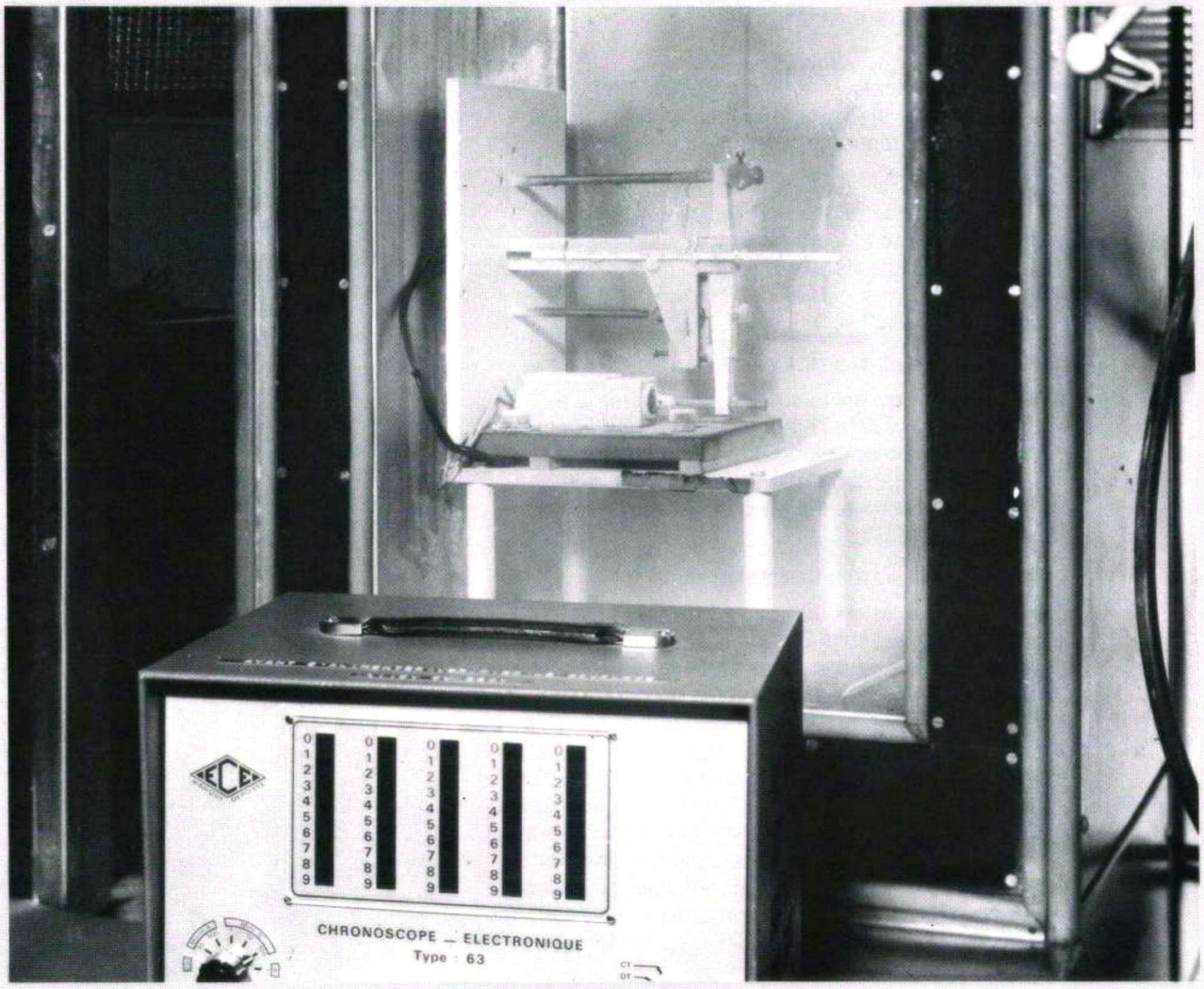
TREATMENT "TK"

For very corrosive atmospheres

The "All Climates" treatment is suitable for mild corrosive atmospheres, such as those containing ammonia, chlorine, soda, etc.
For more corrosive industrial environments Telemecanique offers another special treatment designated "TK".

PERMISSIBLE VOLTAGE VARIATION OF THE CONTROL CIRCUIT

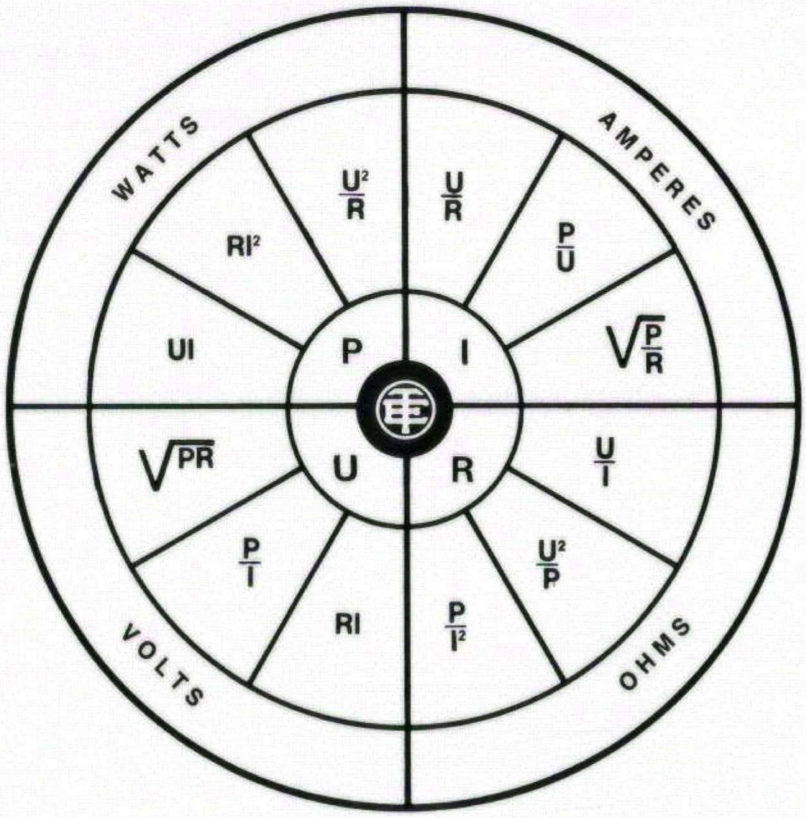
Our contactors close correctly for voltage of 0.85 to 1.1 times the pick up voltage for which they were designed.
Example: for a 220 V coil, the pick up limits are:
V min: 187 V,
V max: 242 V.
The coil can remain energized indefinitely at 1.1 Vn.



Low temperature test of a limit switch XC2-JC.

common formulae

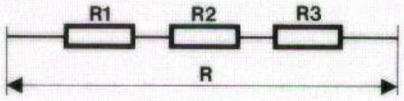
OHM's LAW



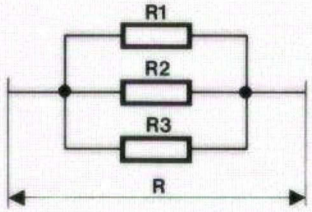
SYMBOLS

U = Voltage in Volts
I = Current in Amperes
R = Resistance in Ohms
P = Power in Watts

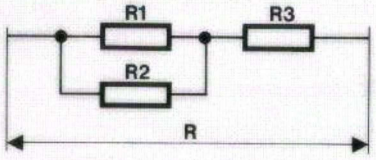
TYPES OF RESISTIVE CIRCUIT



$$R = R_1 + R_2 + R_3$$

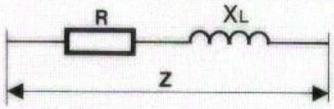


$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} = \frac{R_1 \,.\, R_2 \,.\, R_3}{R_1 \,.\, R_2 + R_2 \,.\, R_3 + R_1 \,.\, R_3}$$

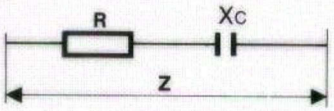


$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} + R_3 = \frac{R_1 \,.\, R_2}{R_1 + R_2} + R_3$$

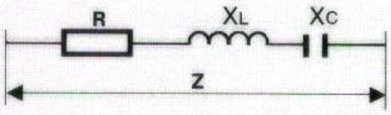
TYPES OF CIRCUIT CONTAINING RESISTANCE AND REACTANCE



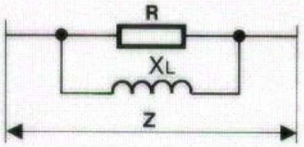
$$Z = \sqrt{R^2 + X_L{}^2}$$



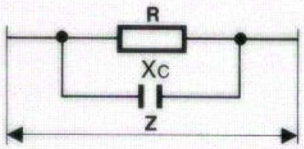
$$Z = \sqrt{R^2 + X_C{}^2}$$



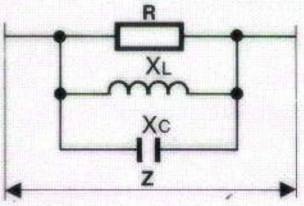
$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$



$$Z = \frac{1}{\sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_L}\right)^2}} = \frac{R \cdot X_L}{\sqrt{R^2 + X_L{}^2}}$$



$$Z = \frac{1}{\sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_C}\right)^2}} = \frac{R \cdot X_C}{\sqrt{R^2 + X_C{}^2}}$$



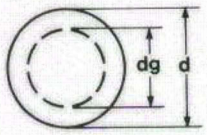
$$Z = \frac{1}{\sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}} = \frac{R \cdot X_L \cdot X_C}{\sqrt{X_L{}^2 \cdot X_C{}^2 + R^2 (X_L - X_C)^2}}$$

• Branch currents flowing through a resistor

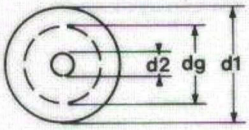
$$i_1 = I \frac{R_2}{R_1 + R_2}$$

$$i_2 = I \frac{R_1}{R_1 + R_2}$$

• Diameter of gyration



$$dg = 0{,}707\ d$$



$$dg = \sqrt{\frac{d1^2 + d2^2}{2}}$$

with d1, d2, d and dg: meters

• Starting or braking time

$$t = 2{,}67 \frac{PD^2}{M} n10^{-3}$$

$$t = 281 \frac{PD^2}{P} n^2 10^{-6}$$

with t: seconds
PD^2: gyration moment in newton meters squared
M: moment of force in newton meters
P: power in watts
n: number of rpm

• Power factor

$$\cos \varphi = \frac{\text{active power}}{\text{apparent power}}$$

• Attractive force of an electromagnet

$$F = \frac{1\ B^2\ S}{981 \times 8\pi \times 10^4}$$

with F: grams
B: teslas
S: cm^2

• Frequency of rotation

Synchronous speed of an asynchronous motor:

$$n = \frac{60\ f}{p}$$

with n: number of r.p.m.
f: supply frequency in hertz
p: number of pairs of poles of the motor

• Motor current

Single-phase:

$$I = \frac{P}{U\ \eta \cos \varphi}$$

Three-phase:

$$I = \frac{P}{U \sqrt{3}\ \eta \cos \varphi}$$

Direct current:

$$I = \frac{P}{U\ \eta}$$

with I: amperes
F: motor power in watts
U: line voltage in volts
η: motor efficiency
$\cos \varphi$: power factor

• Impedance

$$Z = L2\pi f$$

with Z: ohms
L: inductance in henrys
f: frequency of the supply

$$2\pi f = \omega$$

• Joule's law - Energy

$$W = RI^2t$$

with W: joules
R: ohms
I: amperes
t: seconds

• Moment of gyration

$$PD^2 = F(dg)^2$$

with F: newtons
dg: meters
PD^2: newton meters squared

• Active power

Direct current:
$P = UI$
Single-phase:
$P = UI \cos \varphi$
Three phase:
$P = UI \sqrt{3} \cos \varphi$

with P: watts
U: voltage at terminals in volts
I: current flowing through the circuit in ampere
$\cos \varphi$: power factor of the circuit

• Apparent power

Single-phase:
$S = UI$
Three-phase:
$S = UI \sqrt{3}$

with S: volt-amperes
U: voltage at terminals in volts
I: current flowing through the circuit in ampere

• Reactive power

Single-phase:

$$Q = UI \sqrt{1 - (\cos \varphi)^2}$$

or $Q = UIre$

Three-phase:

$$Q = UI \sqrt{3} \sqrt{1 - (\cos \varphi)^2}$$

or $Q = UIre \sqrt{3}$

with Q: vars
U: voltage at terminals in volts
I: current flowing through the circuit in ampere
Ire: reactive current in the circuit in amperes
$\cos \varphi$: power factor of the circuit

• Quantity of electricity

$Q = It$
with Q: coulombs
I: amperes
t: seconds

• Reactance

$$X = \frac{1}{C2 \pi f}$$

with X: ohms
C: capacitance in farads
f: frequency of the supply

• Efficiency

$$\eta = \frac{\text{power output}}{\text{active power input}}$$

• Resistivity

$pt = po^{\circ} (1 + \alpha t)$
With pr and po: ohms
α: temperature coefficient
t: degrees C

• Voltage

Direct current:
$U = RI$
Alternating current:
$U = ZI$
$U = XI$
With U: voltage at the terminals in volts
R: circuit resistance in ohms
Z: circuit impedance in ohms
X: circuit reactance in ohms

names and symbols of the principal units used in electrical engineering

VALUES AND UNITS OF MEASURE

Value		Unit	
Name	**Symbol**	**Name**	**Symbol**
Linear acceleration	a or g	Meters per second squared	m/s^2
Phase angle	α	Radian	rad
		Degree (of arc)	...°
		Minute (of arc)	...'
		Second (of arc)	..."
Capacitance	C	Farad	F
Time constant	τ	Second	s
Current density	J	Ampere per square meter	A/m^2
Diameter	d	Meter	m
Potential difference	U	Volt	V
Heating	$\Delta\theta$	Kelvin or degree Celsius	K ou °C
Energy	E ou W	Joule	J
Thickness	d	Meter	m
Magnetic flux	Φ	Weber	Wb
Force	F	Newton	N
Electromotive force	E	Volt	V
Frequency	f	Hertz	Hz
Frequency of rotation	n	Revolutions per minute	r/min
Slip	s		1
Height	h	Meter	m
Impedance	Z	Ohm	Ω
Inductance	L	Henry	H
Induction	B	Tesla	T
Mutual inductance	M	Henry	H
Magnetic field intensity	H	Ampere per meter	A/m
Current	I	Ampere	A
Width	b	Meter	m
Length	l	Meter	m
Weight or mass	m	Kilogram	kg
Turning moment	T	Meter - newton	N.m
Moment of force	M	Meter - newton	N.m
Pressure	p	Pascal, bar, etc.	Pa
Depth	h	Meter	m
Active power	P	Watt	W
Apparent power	S	Volt-ampere	VA
Reactive power	Q	Var	VAR
Quantity of heat	Q	Joule	J
Quantity of electricity	Q	Coulomb	C
Radius	r	Meter	m
Reactance	X	Ohm	Ω
Reluctance	Rm	1 per henry	H^{-1}
Efficiency	η		1
Resistance	R	Ohm	Ω
Resistivity	ρ	Ohm meter	$\Omega.m$
Surface (area)	A	Square meter	m^2
Temperature Celsius	θ	Degree Celsius	°C
Absolute temperature	T	Kelvin	K
Time	t	Second	s
		Minute	min
		Hour	h
		Day	d

VALUES AND UNITS OF MEASURE (cont'd)			
Value **Name**	**Symbol**	**Unit** **Name**	**Symbol**
Voltage	U	Volt	V
Work	W	Joule	J
Angular velocity	φ	Radian per second	rad/s
Linear velocity	v	Meter per second	m/s
Volume	V	Cubic meter	m^3
References: International Units System (SI): I.E.C. Document 27 (1971), etc.			

SUB-MULTIPLES OF UNITS			MULTIPLES OF UNITS		
Prefix	**Symbol preceding the unit**	**Multiplication factor**	**Prefix**	**Symbol preceding the unit**	**Multiplication factor**
déci	d	10^{-1}	déca	da	10^{1}
centi	c	10^{-2}	hecto	h	10^{2}
milli	m	10^{-3}	kilo	k	10^{3}
micro	μ	10^{-6}	méga	M	10^{6}
nano	n	10^{-9}	giga	G	10^{9}
pico	p	10^{-12}	téra	T	10^{12}
Examples: Five nanofarads = 5 nF = 5.10^{-9}F Two milliamperes = 2 mA = 2.10^{-3}A Eight micrometers = 8 μm = 8.10^{-6}m			**Examples:** Two megajoules = 2 MJ = 2.10^{6}J One gigawatt = 1 GW = 10^{9}W Three kilohertz = 3 kHz = 3.10^{3}Hz		

• Time notation

To indicate an instant t it is written in the order: year, month, day, hour, minute and second. When there is any doubt, + is placed before the year for periods after the year zero and — is used for periods before the year zero. March 30, 1977 at 17 hours 15 minutes 40 seconds will be written:
+ 1977 03 30d 17h 15min 40sec.
Abbreviated, the date becomes:
77.03.30 or 770330.

• Current practice for writing units with the sub-multiples

The unit figure is written in large numbers and the sub-multiples in small numbers and underlined.
Examples:
17 hours 15 minutes = $17^{\underline{15}}$.

conversion tables

CONVERSION TABLES

LENGTH

From \ to	m	in.	ft	yd
1 meter (m)	1	39,37	3,281	1,094
1 inch (in or ")	0,0254	1	0,08378	0,02733
1 foot (ft or.')	0,3048	12	1	0,3333
1 yard (yd)	0,9144	36	3	1

AREA

From \ to	m^2	sq. in.	sq. ft	sq. yd
1 square meter (m^2)	1	1,550	10,76	1,196
1 square inch (sq. in.)	—	1	—	—
1 square foot (sq. ft)	0,0929	144	1	0,111
1 square yard (sq. yd)	0,8361	1 296	9	1

VOLUME

From \ to	m^3	dm^3	cu. in.	cu. ft	cu. yd
1 cubic meter (m^3)	1	1 000	—	35,3146	1,3079
1 cubic decimeter (dm^3) (litre)	0,001	1	61,02	0,035	0,0013
1 cubic inch (cu. in.)	—	0,0164	1	—	—
1 cubic foot (cu. ft)	0,0283	28,32	1,728	1	0,0370
1 cubic yard (cu. yd)	0,7645	764,5	46,656	27	1

WEIGHT

From \ to	kg	oz	lb
1 kilogram (kg)	1	35,27	2,205
1 ounce (oz)	0,028	1	0,0625
1 pound (lb)	0,454	16	1

PRESSURE

From \ to	N/m^2	bar	psi
1 newton per square meter (N/m^2) or pascal (Pa)	1	10^{-5}	$1{,}45\ 10^{-4}$
1 bar (bar)	10^5	1	14,504
1 pound per square inch (psi)	6 894	0,068947	1

ANGULAR VELOCITY

From \ to	rad/s	r.p.m.
1 radian per second (rad/sec)	1	9,5238
1 revolution per minute (rpm)	0,105	1

POWER

From \ to	W	ch	Hp	ft-lb/s
1 watt (W)	1	$1{,}36\ 10^{-3}$	$1{,}341\ 10^{-3}$	0,7376
1 cheval (metric H.P.) (ch)	736	1	0,9863	542,5
1 horse power (H.P.)	745,7	1,014	1	550
1 ft. lb/s	1,356	$1{,}843\ 10^{-3}$	$1{,}818\ 10^{-3}$	1

FORCE

From \ to	N	kgf	pound weight	pdl
1 newton (N)	1	0,102	0,225	7,233
1 kilogram force (kgf)	9,81	1	—	—
1 pound weight (lb)	4,448	—	1	—
1 poundal (pdl)	0,138	—	—	1

ENERGY - WORK - HEAT

From \ to	J	cal	kWh	B.t.u.
1 joule (J)	1	0,24	$2{,}78\ 10^{-6}$	$9{,}5\ 10^{-4}$
1 calorie (cal)	4,1855	1	—	—
1 kilowatt hour (kWh)	$3{,}6\ 10^{6}$	—	1	—
1 British thermal unit (B.t.u.)	1 055	—	—	1

MAGNETIC FLUX - MAGNETIC INDUCTION

		wb	M	T	G
FLUX	1 weber (Wb)	1	10^{8}	—	—
	1 maxwell (M)	10^{-8}	1	—	—
INDUCTION	1 tesla (T)	—	—	1	10^{4}
	1 gauss (G)	—	—	10^{-4}	1

TEMPERATURE

Can be expressed by means of 2 equal units:
the kelvin (K) or the degree Celsius (°C).
— Temperature in kelvin = temperature in degrees Celsius + 273.15.
— Temperature in degrees Celsius = temperature in kelvin — 273.15.
Conversion between Fahrenheit and Celsius:

$$\text{— Temperature in degrees Celsius} = \frac{5}{9} \text{ (temperature in degrees Fahrenheit — 32).}$$

$$\text{— Temperature in degrees Fahrenheit} = \frac{9}{5} \text{ (temperature in degrees Fahrenheit) + 32.}$$

motor current

• The powers and currents are those specified by standards or generally encountered internationally.

• For three phase a.c. motors, the figures tabulated are for a 4 pole squirrel cage motor, 50 or 60 Hz.

• The characteristics shown in tables of Telemecanique contactors and starters are based on the powers shown below.

POWER		CURRENT							
		three phase 50-60 Hz						1 φ.	d.c.
kW	h.p.	220 V	380 V	415 V	440 V	500 V	660 V	220 V	220 V
0,37	0,5	1,8	1,03			1	0,6	3,12	2,26
0,55	0,75	2,75	1,6			1,21	0,9	4,76	3,31
0,75	1	3,5	2	2	1,68	1,5	1,1	6,01	4,29
1,1	1,5	4,4	2,6	2,5	2,37	2	1,5	7,6	6,35
1,5	2	6	3,5	3,5	3,06	2,6	2	10,4	8,25
2,2	3	8,7	5	5	4,42	3,8	2,8	15,1	12,3
3	4	11,5	6,6	6,5	5,77	5	3,8	20	16,2
4	5,5	14,5	8,5			6,5	4,9	25,1	21,6
5,5	7,5	20	11,5	11	10,4	9	6,6	34,6	29,2
7,5	10	27	15,5	14	13,7	12	8,9	46,8	38,4
10	13,5	35	20			15	11,5	60	52
11	15	39	22	21	20,1	17	12,7	68	57
15	20	52	30	28	26,5	23	17,3	90	76
18,5	25	64	37	35	32,8	28,5	21,3	111	94
22	30	75	44	40	39	33	25,4	130	113
30	40	103	60	55	51,5	45	34,6	178	150
37	50	126	72,5	66	64	55	41,8	218	186
45	60	147	85	80	76,3	65	49	254	221
55	75	182	105			80	60,6	315	276
75	100	239	138	135	125	105	79,6	414	364
90	125	295	170	165	156	129	98	511	450
110	150	356	205	200	186	156	118	617	540
132	175	425	245	230	216	187	141	710	630
160	220	520	300			228	173	900	791
200	270	640	370			281	214	1 108	971
220	300	710	408	385		310	235	1 230	1 079
250	350	823	475	450		360	274	1 426	1 259
315	430	1 000	584			442	337	1 728	1 547

calculation of starting resistance and autotransformer values

FOR SQUIRREL CAGE MOTORS

Resistance for 3 step star delta starting

$$R = \frac{0.28\ U}{In}$$

with R: ohmic value of the resistance per phase
U: supply voltage
In: rated motor current

To order a resistance indicate the resistance connection time (one quarter of the time in star) and the number of starts per hour.

Primary resistance

3 phase

$$R = 0.551 \frac{U}{In}$$

with R: ohmic value of the resistance per phase
U: supply voltage
In: rated motor current

To order a resistance indicate the resistance connection time and the number of starts per hour.

2 phase

$$R = 0.0953 \frac{U}{In}$$

Autotransformer

During starting:
U motor = k x U line;
C motor = k^2 x C;
I line $\neq$ k^2 x I;
I motor = k x I.
with k: voltage ratio of the autotransformer

$$\text{i.e.: } \frac{U\ \text{output}}{U\ \text{line}}$$

C: direct on line starting torque;
I: direct on line starting current.

To order an autotransformer, indicate:
— the peak current of the motor with direct on line starting (given by the motor manufacturer);
— the value of the output voltage with respect to the supply voltage expressed as a percentage;
— the switch on time of the autotransformer;
— the number of starts per hour.

FOR SLIPRING MOTORS

ROTOR CURRENT

with Ir: rotor current
Ur: rotor voltage
P: power in kilowatts

UNIT RESISTANCE*

Three phase

$$Ru = \frac{333\ P}{I_r^2}$$

with P: power in kilowatts

Two phase

$$Ru = \frac{500\ P}{I_r^2}$$

with P: power in kilowatts

* Unit resistance is the theoretical value of the total resistance of the rotor circuit to obtain, with locked rotor, the rated torque. It is essential in determining the starting resistance.

VALUE OF THE RESISTANCE

$$R\ \text{total} = \frac{Ru}{1\text{st peak}} - r$$

with R total: value of the resistance per phase
Ru: unit resistance
r: internal resistance of the motor
1st peak: desired current peak on starting

INTERMEDIATE VALUES OF THE RESISTANCE

$$s = \frac{Rp + r}{Peak} - r$$

with s: value of the resistance per phase for this step
Rp: resistance of the preceding step
r: internal resistance of the motor
Peak: desired current peak for this step

PEAK ON LAST STEP

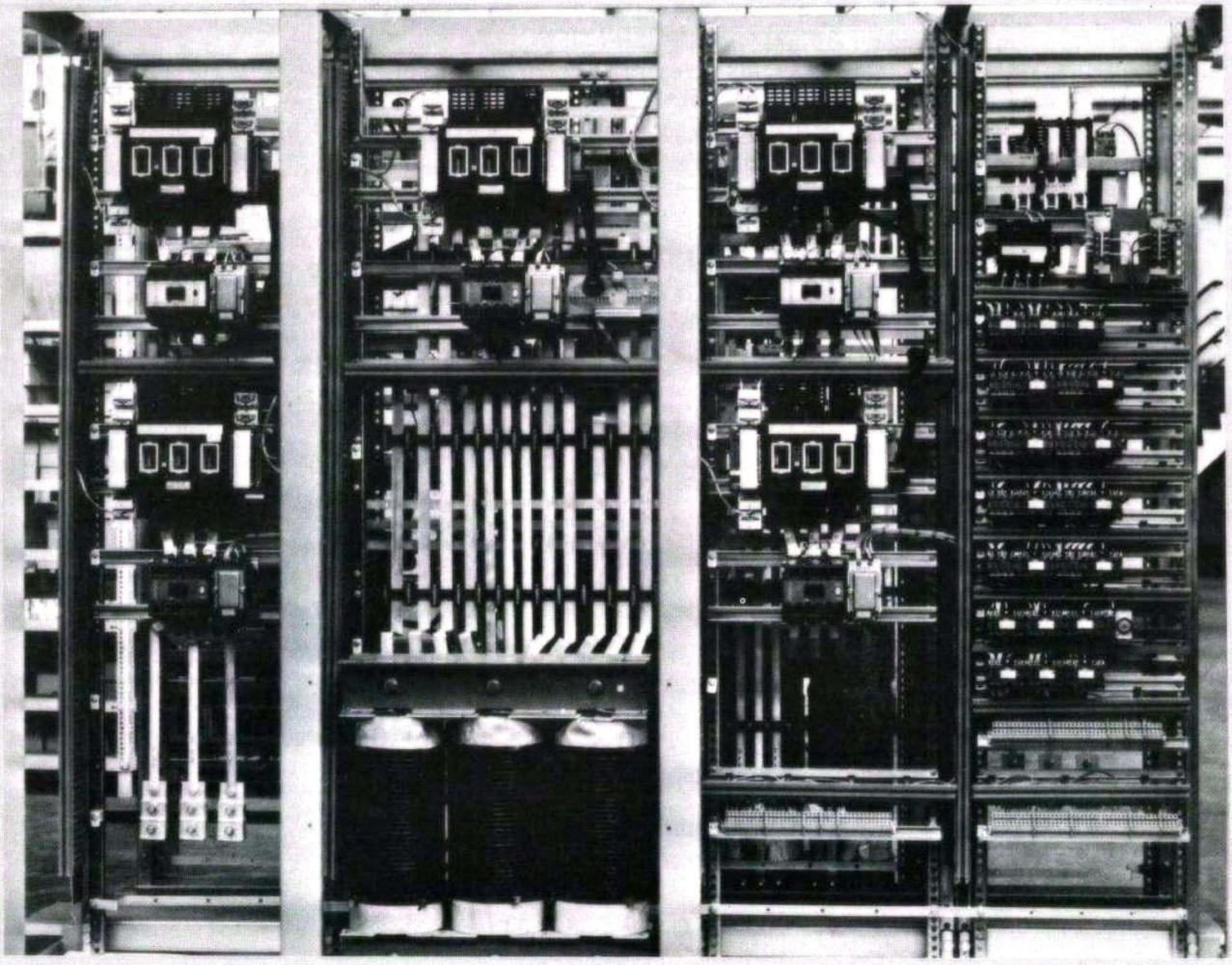
$$Peak = \frac{Rp + r}{r}$$

with Peak: current peak
Rp: resistance of the preceding step
r: internal resistance of the motor

OTHER CHARACTERISTICS

$$I\ \text{average} = Ir \frac{Ip - Ir}{3}$$

with Ir: rotor current;
Ip: current peak.



Control panel incorporating autotransformer starting.

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Telemecanique

Division Internationale
Immeuble Colisée-Défense
50/64, avenue François Arago
92022 Nanterre Cedex - France
Tél. (1) 784.74.37

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